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THE HAWAIIAN PLANTERS' RECORD

Volume XXXIV. JANUARY, 1930 Number 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Gumming Disease of Sugar Cane:

Gumming disease is considered one of the oldest maladies affecting sugar cane. Through the importation of diseased cuttings the malady has spread from one cane country to another, often resulting in serious losses. It now occurs in nine different sugar cane countries.

In this issue the following points regarding the disease are presented: the geographic distribution and history, the description of the disease and of the symptoms used in diagnosis, the tissues affected, description of the causal organism and its transmission, and methods used in controlling the disease.

To date the most effective control has been secured through the substitution of resistant varieties. In areas affected with gumming disease new cane varieties should be tested as soon as possible in order to establish their resistance to gumming disease.

Eye Spot and Brown Stripe:

The results of several years' observations on eye spot resistance on a large number of cane varieties are presented in tabular form. Those canes of agricultural promise which appear in Groups I or II should be preferred for trials or spreading in eye spot areas to the canes appearing in Groups III or IV. No mention is made in this paper of the agricultural qualities of the canes in question.

Those varieties listed which are preceded by an asterisk, have, at one or more times, been found susceptible to mosaic disease.

The number of observations made on each variety is noted. Conditions in the fields or plots, where the growing canes have been observed, have been made favorable by fertilization for the production of eye spot epidemics. In all cases H 109 cane has been used as the standard for comparative purposes.

In Part II of this paper are recorded observations on a limited number of cane varieties in reference to their relative resistance and susceptibility to brown stripe disease.

It will be observed that, in many cases, those varieties which have shown marked resistance to eye spot disease have a very marked susceptibility to brown stripe disease. Due to the relatively recent determination of the latter disease, a lesser number of observations have been made on a smaller number of cane varieties. Further observations will be made and more data presented on this problem at a later date.

Notes on Pythium Root Rot:

It has been shown in recent papers that nitrogeneous soil amendments greatly increase *Pythium* rot of Lahaina cane roots. The continued vigorous root growth of H 109 cane in parallel experiments has been reported as of practical significance. In this issue further observations on certain soil factors which influence the activity of the *Pythium* fungus and determine the degree of rot are recounted.

Experiments showed that the roots of H 109 break down under *Pythium* attack if the soil is heavily amended with stable manure. With amendments of 50 to 75 per cent by volume of stable manure the effect on H 109 roots is comparable with the effect of 5 to 10 per cent amendments on Lahaina roots. The high concentration of nitrogeneous material required to induce susceptibility of H 109 roots is not likely to occur in the field, or to be of long duration if accidentally reached in restricted areas. It was noticed that after a time, apparently when the concentration had become reduced, sound root growth was resumed. Further studies are required to determine the relation of lack of balance of nutrients to root rot.

The effect of molasheake in increasing *Pythium* rot has been mentioned. It was found in the present studies that molasses and press cake, the chief nutrient materials in molasheake, stimulated growth and were active in producing conditions favorable for root rot of Lahaina. Bagasse had the opposite effect, growth was depressed and no root rot occurred. This observation suggests a possibly useful role for bagasse as a soil amendment in suitable combinations with molasses to retard reactions, extend beneficial effects and check harmful tendencies.

Experiments are cited to show that nitrogeneous materials do not in themselves cause root collapse. It is inferred that they act indirectly by stimulating root growth to the point where it becomes susceptible to *Pythium* attack.

Some of the modifications of a healthy soil necessary to bring on root rot having been determined, an experiment to demonstrate the reverse effect was conducted. Soil from Olaa which is notoriously "sick" for Lahaina cane, was diluted progressively with "healthy" Makiki soil, and the effect on Lahaina roots observed. Improvement in root condition was marked when the sick soil constituted one-half or less of the mixture. Rotting of the roots was negligible where the sick soil was but 20 per cent of the mixture.

In view of the present and earlier experiments it seems obvious that *Pythium* root rot varies in severity with the concentration of stimulative nutrients in the soil.

Iron Sulphate Spray for Coral Chlorosis:

In a test conducted cooperatively with Ewa Plantation Company, using a 5 per cent solution of iron sulphate spray on short ratoons, a gain of nearly 35 per cent was obtained in favor of the spray. This gain represented 15.88 tons of cane and 1.8 tons of sugar.

Iron sulphate spray can be applied to correct coral chlorosis on a field scale at a very low cost.

A Study of Sugar Cane Roots:

A study is made of the development of roots of the sugar cane plant from the root primordia, which occur as "root dots" on the "root bands" of the stems. A number of varieties are compared as to the number and per cent of root primordia developing into seed-piece roots and as to the number of shoot roots developing at intervals of 5, 10, 15, 25 and 50 days after the seed piece is planted. The number of roots primordia and, therefore, the possible number of seed piece roots per node varies greatly for the varieties studied.

At the end of a 5-day period, for example, on ten H 109 seed pieces, 139 root primordia, or 3.6 per cent of the total possible, had developed into seed-piece roots, while on the same number of Yellow Caledonia seed pieces, 2,871 root primordia, or 64.6 per cent, had developed into seed-piece roots. The percentage of root primordia developing into seed-piece roots on seed pieces 50 days after planting is very little higher, if any, than for seed pieces from 5 to 25 days after planting. A certain number of root primordia are held in reserve and develop only in case of need. The total per cent of root primordia developing into seed-piece roots was less for seed pieces left in the ground undisturbed for 50 days than for seed pieces removed from the soil, the developing roots cut off, and the seed pieces replanted at intervals of 5, 10, 15 and 25 days for the same period.

No correlation exists between the number of root primordia of different varieties and the development of the shoots from the buds, which does not preclude a correlation between development of shoots (stand of cane) and the number of root primordia for a given variety.

Shoot roots developed from the root primordia of the bud and pushed out from between the bud scales as early as 5 days after the seed pieces were planted.

For the varieties studied the number of shoot roots developing on shoots from seed pieces undisturbed for 50 days *exceeded* the average of the number developing on shoots from seed pieces disturbed at intervals of 5, 10, 15 and 25 days. This is in contrast with the data for the seed-piece roots, for, without exception for the same varieties, the percentage of seed-piece roots developing on seed pieces undisturbed for 50 days *was less* than the average of those developing on seed pieces disturbed at intervals of 5, 10, 15 and 25 days.

These facts may help interpret the significance of various types of root injury and may have a practical application to the practice of off-barring and sub-soiling. *The "pruning" of the seed-piece roots stimulated into development root primordia of the seed pieces which under normal conditions would have been held in reserve.*

The "pruning" of the shoot roots resulted in fewer roots being developed from the shoots.

Molasses as a Fertilizer:

During the recent low price of molasses considerable interest was manifested in its value as fertilizer. It had been formerly believed that molasses was injurious toward cane growth. During this period of low price some few plantations made field applications of molasses which gave notable improvement in cane growth. In this paper some effects of molasses fertilization have been studied which lead us to believe that molasses will react, much like a fallow toward an infertile soil. Soil conditions in field showing both injury and benefit have been studied. Injury occurs in poorly drained soils or soils high in "active" aluminum. Benefit is obtained from better soil aeration and a rejuvenation of the biological soil flora.

Pahala Blight:

An article appearing in this number presents data upon the Pahala blight, namely, the ash, iron and manganese content of leaves as related to chlorosis and as affected by sulphur fertilization.

Oriental Rice Borers and Their Parasites:

This paper is a short report on the work done in the Orient: Japan, Formosa, and China, in the year 1928, in searching for parasites of the rice borer. Eighteen different species of parasites or predators were found more or less effectively controlling the rice borer in the Orient. About ten species of these parasites were successfully sent or brought to Honolulu, and arrived alive. They were either turned loose to shift for themselves in the rice fields, or were raised through several generations in the laboratory and then released.

Three species of these parasites have been recovered in the field, and their establishment thus verified. They are: the egg-parasite *Trichogramma japonicum* Ashm., and two larval parasites, *Amyosoma chilonis* Vier., and *Diocles chilonis* Cushm. It is possible that some of the other species of parasites have become established, but are still too scarce to be recovered.

All of this work on borer parasites is of interest to sugar planters for the reason that some of the rice borers of the Orient attack sugar cane as well as rice, though the one now occurring in Hawaii does not attack cane.

Cane Breeding in Formosa:

Formosa, like Hawaii, is near the climatic limit for cane growing, and especially for cane breeding. The fertility of the tassels of a given variety is much lower in the cooler regions than in more tropical countries, and many varieties do not

tassel at all. Formosa is fortunate, however, in being able to carry on much of its breeding work at a Japanese-owned plantation in Java, the tassels being shipped when ripe to Formosa for planting.

The possibilities in cane breeding are fully appreciated in Formosa. About 300,000 seedlings have been germinated since the work was started in 1914 and at present about 50,000 seedlings are being grown each year. Special attention is being given to seedlings of P. O. J. 2364, P. O. J. 2725, and other parents which have been used with success in Java.

In the early period of the Formosan industry canes of the Uba type were almost exclusively grown. With the advent of Japanese capital, modern mills and improved cultural methods, Striped Mexican imported from Hawaii became the principal variety. It was, in turn, replaced by P. O. J. seedlings of Chunnee blood, especially P. O. J. 36, P. O. J. 105 and P. O. J. 161. During the last three years these have rapidly given way to the newer P. O. J. seedlings of Kassoer derivation, especially P. O. J. 2725 and P. O. J. 2714, which now occupy most of the 290,000 acres in cane.

Considerable interest is being taken in P. O. J. 2878, but whether it will be able to outyield the present varieties is still questionable.

In this issue a paper is presented which caries a detailed discussion of the technic followed in the recently developed asphaltic sealing of earth reservoirs.

Descriptions and photographs of the California system of oil treatment of reservoirs are included.

Lippincott and Standard Oil Company specifications are given for the impregnation and hardening of an asphaltic soil treatment and also for preparing and applying a mastic ditch lining.

The Parshall Measuring Flume

The Improved Venturi Flume is hereafter to be known as the Parshall Measuring Flume, according to J. C. Stevens, secretary of the Special Committee on Irrigation Hydraulics, who writes as follows:

> This committee has felt for some time that the name, "Improved Venturi Flume," as developed by R. L. Parshall, Associate Member, American Society of Civil Engineers, for measuring irrigation water in the West, is a misnomer. We also felt that the name could well be changed to in some way give Mr. Parshall credit for this development. We took this matter up with the Executive Committee of the Irrigation Division, and also with S. H. McCrory, Member, American Society of Civil En-

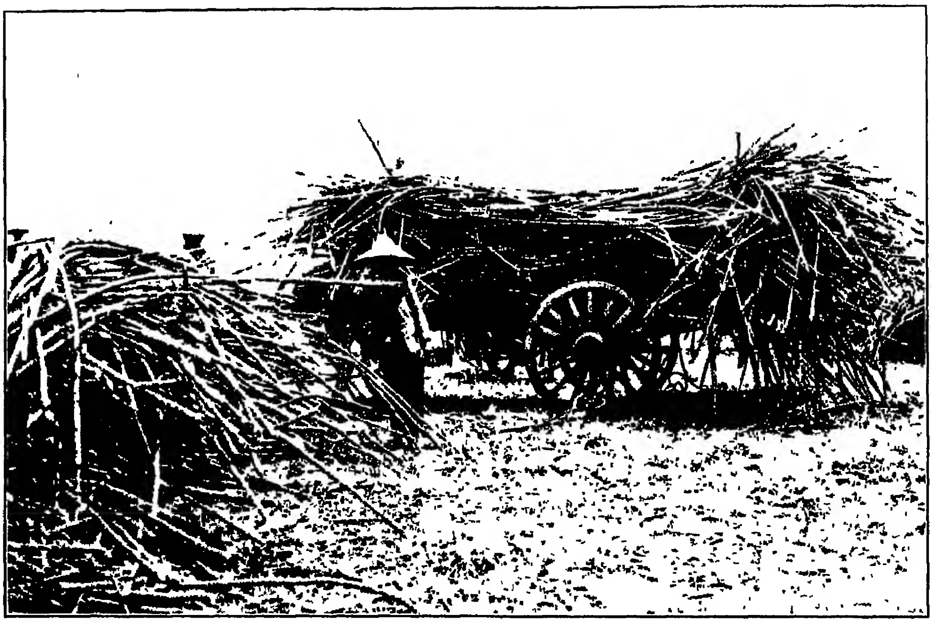
gineers; Professor W. W. McLaughlin, Associate Chief, Division of Agricultural Engineering, U. S. Department of Agriculture; and C. A. Lory, President, Colorado Agricultural College, who recognized the desirability of a change of name. Accordingly, at its last meeting this committee unanimously adopted a resolution proposing to change the name from "Improved Venturi Flume" to "Parshall Measuring Flume."

Formosan Views

A Formosan farmstead

P. O. J. 2878 under trial in Formosa.

Formosan field laborers.



Formosa: A harvest scene, P. O. J. 161, formerly the leading variety.

A farmhouse, Formosa.

Cane Varieties in Formosa

By A. J. Mangelsdorf

It should be mentioned at the outset that there is very little ratooning in Formosa. The greater part of the crop is plant cane. One reason for this is that the cost of field operations, such as plowing and planting is low, due to the relatively low cost of labor. Plant yields have been found to exceed ratoon yields by a sufficient margin to more than offset the cost of planting operations.

It is likely that the pronounced dry season in the southern two-thirds of the island plays an important part in the rather marked decline in the yield of ratoons as compared with plant. After a field is harvested, it may lie for two or three months, baking in the sun until the rains begin and the roots receive enough moisture to start off the ratoons.

In the northern part of the island there is an abundant supply of irrigation water, and whereas in the south only the rice is irrigated, in the north there is enough water for both cane and rice. Here, P.O.J. 2714 is the principal cane, and one ratoon crop is the rule.

P. O. J. 2725 in Formosa. This is the leading variety at present. It is drought resistant and has good juices.

P.O.J. 2725 continues as the leading variety in Formosa. It now occupies about half of the total area. It is preferred especially in the south, under unirrigated conditions, where, as has been mentioned, the winters are very dry. Much of the cane which we saw had had almost no moisture for three months or more,

nor was it likely to receive any until around June, during which month the summer rains usually start. Its ability to withstand drought might make this cane a useful one for the Kohala district. It tassels very heavily, as in Hawaii, but probably because of the dry, cool winters it undergoes very little deterioration before April, by which time harvesting is practically finished. P.O.J. *2725* has been found in Formosa to be extremely resistant to mosaic.

P.O.J. 2714, as has been mentioned, is the leading variety in the north, where the climate is cooler and the moisture more abundant. It now occupies about one-fourth of the total cane area of Formosa. The fact that the only extensive ratooning practiced in Formosa is with this variety would seem to indicate that it must be a fairly satisfactory ratooner, a point of considerable interest to us.

P.O.J. *2727* has increased slowly during the past two or three years and now occupies about 7 per cent of the total cane area. It does not tassel as heavily as P.O.J. *2725*. However, Mr. Ebi, agriculturist for the large Taiwan Sugar Company, is of the opinion that neither P.O.J. *2714* nor *2727* hold over as well as *2725*.

P.O.J. 161, 105 and 36, at one time the three most important varieties in Formosa, continue to decline in acreage, and will soon be entirely replaced by the newer P.O.J.'s. The three together still occupy about 15 per cent of the total cane area.

The fact that P.O.J. 36 is being replaced in Formosa need not necessarily discourage its spreading in Hawaii. Conditions in the two countries differ in a great many respects. Formosa has no weed problem, it does little ratooning, its winters are dry while its summers are wet, and, finally, it does not grow cane at high elevations. With the rather marked differences in conditions it would not be particularly surprising to see a cane which had been replaced in the one country succeeding in the other.

Of the Formosan seedlings only F. 4 and F. 19 have been planted on a large scale. Both reached a peak last year, when F. 4 occupied 7000 acres, and F. 19 about 17,000 acres. Their acreage this year has declined somewhat. Evidently they are being replaced by P.O.J. *2725*.

Badila is grown throughout the island as a chewing cane. Its total area is listed at over a thousand acres. Chewing cane is sold in every village by street venders and in the markets it is prepared for sale by carefully trimming away the eyes and washing and polishing the stalks, after which it is cut up into lengths of about eighteen inches each. Some is shipped to ports in China. We saw in Amoy Badila which had evidently come from Formosa.

We saw a number of P.O.J. 2878 nurseries during our stay in Formosa. This cane is being spread rapidly, although figures as to its yielding ability, in comparison with the present varieties, are not available. There is some difference of opinion as to whether it will replace P.O.J. *2725*. The majority of those who were willing to venture an opinion seem to feel that it gives promise of outyielding the varieties now being grown. It is said to carry over well and to make a very rapid growth during the hot, moist summer months.

It is evident that Formosa is preparing to give P.O.J. 2878 a thorough trial.

Cane Breeding in Formosa

By A. J. Mangelsdorf

The experimental work in connection with the Formosan sugar industry is carried on mainly at the Shinka Station. This station is located at Shinka near Taiwan, in the south-central part of the island.

The Shinka Station is a branch of the Central Research Institute, a government organization, the agricultural division of which performs much the same functions as our U. S. Department of Agriculture.

There are forty-eight factories on the island. Many of these employ their own agriculturists who also carry on experimental work in connection with varieties, fertilizers and cultural practices.

The Shinka Station has at its disposal 375 acres of land. A three-year rotation is followed. Each year about 100 acres are planted to cane, with the remainder in rice, sweet potatoes and leguminous crops, especially *Sesbania* and *Mucuna glauca*. The leguminous crops are grown for turning under as green manure. This is a general practice and is believed to be more economical than a system of continuous cropping, which would necessitate larger purchases of commercial fertilizers from abroad.

Newly potted seedlings at the Sugar Experiment Station, Shinka, Formosa. From 30,000 to 70,000 are grown each year. They are subjected to three or four years of testing by the Station. The poorer ones are eliminated and only the best are given to the plantations for final trials.

The cane breeding at Shinka Station is carried on under the supervision of Dr. Kaneko, the director. Associated with him in this work are Dr Sakamoto and his assistant, Dr Hisatomi.

The first crosses were made in 1914, since which time a total of almost 300,000 seedlings have been grown. During the past few years the number has ranged from 30,000 to 70,000 yearly.

Nursery Procedure

The methods followed in germinating the seedlings are much the same as those practiced in Hawaii. The Shinka Station, however, lacks the greenhouses and heated tables which have been so helpful in Hawaii in reducing mortality in the early stages.

The fuzz is sown in flats, which are placed on unheated tables covered with glass hot-bed sash. When they reach a height of several inches they are transplanted to rather large earthenware pots, each about 8 inches in diameter.

Crosses being made in Java for the Formosa Station. Each year a member of the Formosa Station staff goes to Gedarea in Java, a plantation owned by a Japanese syndicate, to make crosses. The fuzz is shipped to Formosa when ripe and is planted at the Shinka Station.

The growth of the seedlings in the nursery appears to be quite slow as compared with what we are accustomed to expect in Hawaii. This may be due to their rather cool winter season, or it may be that the potting soil used in the nursery is not entirely suitable.

Crossing Program

The climate in Formosa is rather unfavorable for crossing. Many varieties fail to tassel, and many which produce fertile pollen elsewhere are unfertile in Formosa.

To escape this handicap the station began in 1922 to make crosses at Gedaren, a Japanese-owned plantation in Java, where conditions are very favorable for crossing work.

Each year a member of the Shinka staff goes to Java to supervise the crossing at Gedaren. Dr. Sakamoto was in Java for this purpose during 1929.

When ripe, the crossed tassels are sent to Formosa for germination. In view of the presence in Java of a number of serious diseases this policy might seem to be rather a hazardous one. Great care is exercised, however, in the fumigating and disinfecting of the imported tassels and the Station staff feel that very little hazard is involved. Dr. Miyake, the pathologist, told us that in the seven years during which fuzz has been imported from Java he has not found a single instance of disease being introduced with the fuzz.

Crossing Method

The sulphurous acid method is not used in Formosa. The crosses are made in the field. The female tassel is bagged with a large cloth bag about 20 inches in diameter and 10 inches long. The bag is supported by a bamboo pole. The male tassel is cut, placed in a bamboo vase containing water and tied in position within the bag in contact with the female. The fact that the male tassel is in water rather than in sulphurous acid solution necessitates replacing it with a fresh one each day during the blooming period of the female. This naturally requires considerable labor, but labor is abundant and cheap, which means that practices which are prohibitive in Hawaii may be entirely practicable here.

Selection of Seedlings

The selection procedure is similar to that practiced in Hawaii. The seedlings are planted in the field when they have reached a height of a foot or so. Each plant is given about two and one-half feet of space in the row, with about four feet between rows.

The first selection is made when the seedlings are a little less than a year old. About 10 per cent of them, on the average, are retained for a second trial. Ten seed pieces are cut from each of the selected seedlings. The seed is so spaced in planting that each seedling comes to occupy about fourteen feet of row in the second field trial. Every third row is a check row of P. O. J. 2725, the standard variety at Shinka.

The seedlings surviving the second selection are planted in blocks, each consisting of three 14-foot rows. Here again every third block is a check of P. O. J. 2725.

Subsequent selection is based on the harvesting results from checkerboard experiments. Each plot in these checkerboard tests contains about one-twentieth

acre. The tests are planted at the various factories as well as at the Shinka Station. Wherever possible ten replications of each seedling is the standard practice in these tests.

In addition to the seedlings grown by the Station, one of the factories, the Ako Sugar Mill at Heito is also growing about 10,000 seedlings a year.

All of the factories visited are keenly interested in testing the seedlings produced by the station. This interest extends even to the Chinese farmers, by whom most of the cane is grown under contract with the nearest mill.

The widespread interest in seedlings may be attributed to the success of certain of the seedlings which have been distributed during recent years, at first P. O. J. 105, 161 and 36, and more recently P. O. J. 2725 and 2714, all of which have had a part in the remarkable increase in yield of sugar per acre in Formosa.

Parent Material Used in Breeding

The history of the crossing work in Formosa falls into two distinct divisions. During the first period, which includes the years from 1914, when the work was begun, to 1923, P. O. J. seedlings with Chunnee blood were the leading varieties in Formosa and it was only natural that they should be the ones most extensively used in crosses.

The most important of these early P. O. J.'s of Chunnee derivation were P. O. J. 105, which was used both as a male and as a female in crosses, P. O. J. 143, 161, 920 and 1507, which were used as females, and P. O. J. 181 which was used very extensively as a male. These canes were crossed among each other and thus many of the combinations tried were brother-sister or half-brother-half sister crosses. This fact may possibly account for the relatively small number of good seedlings obtained from combinations of this type. The seedlings also tended to have poor juices.

It is of interest to note that attempts were also made to use P. O. J. 36 in crossing. As in Hawaii and in other countries as well, it proved to be completely sterile.

The second period in the crossing work began when Formosa followed the lead of Java in the use of Kassoer blood. P. O. J. 2364 and 2725 are most extensively used. They have been crossed especially with P. O. J.'s and Formosan seedlings containing Chunnee blood, theoretically a promising line of attack.

Attention during the present crossing season is again being centered on crosses with canes of Kassoer derivation. There is also some interest in Uba crosses. E. K. 28, S. W. 111 and S. W. 499 are favored as males.

Many sister-brother crosses between P. O. J. 2725 and 2878 and also many mother-son crosses between P. O. J. 2364 and 2878 are also being tried this season. It remains to be seen whether seedlings resulting from such close matings as these will have the desired vigor.

Results of Breeding Work

Those seedlings which give promise of becoming commercial canes are given permanent F numbers. The F series includes at present 76 seedlings. Only two

of these have been planted on a large scale. F 4 is holding its own with about 7,000 acres, while F 19 has declined from its peak of 17,000 acres to around 9,000 acres. The acreage which it has lost has been taken up for the most part by P. O. J. 2725. Of the newer F seedlings 49, 58 and 63 are thought to be promising. The last mentioned seedling, however, appears to be quite susceptible to mosaic.

In conclusion, it may be said that the breeding work if continued on its present scale bids fair to keep the Formosan industry supplied with new seedlings which should be able to maintain, if not to exceed, the present yields. Selection is not so difficult as in Hawaii. There is very little ratooning in Formosa, by far the greater part of the acreage is plant cane. This is probably due largely to the fact that with cheap labor the cost of preparing and planting is low, and plant yields exceed ratoons by a sufficient margin to pay for the additional cost. The absence of ratooning naturally simplifies the selection work, since it is not necessary to wait for several years to determine whether a promising seedling will ratoon. Furthermore, since almost the entire area is replanted each year it can be quickly changed over to a new variety should a superior one be found. The variety census shows that as compared with Hawaii, for example, the acreages of the different varieties have changed with great rapidity. The further fact that conditions are fairly uniform in most of the cane growing area also simplifies the selection problem.

Pahala Blight
II

By W. T. McGeorge

It was experimentally shown by investigations conducted in 1924 and 1925 that sulphur, as a soil amendment, brought about a rapid recovery of cane afflicted with chlorosis at Hawaiian Agricultural Company In about 2,000 acres on this plantation cane yields had for many years been greatly reduced by a form of chlorosis, which had come to be known as Pahala blight. The corrective value of sulphur has now been thoroughly established.

The research work connected with this problem was published in the 1926 *Planters' Record* (1) and preceding quantitative field experiments The evidence at that time strongly indicated that some factor, probably the high ash content of the plant, was interfering with the proper functioning of the iron. Iron determinations, by the gravimetric method, which admittedly are not well adapted for determining such small amounts of iron as are present in plants unless a very large sample is used for analysis, indicated no relation to the chlorosis. On the other hand, injecting iron into the growing stalk of chlorotic cane, and even injecting dilute sulphuric acid to increase the mobility of the iron already present in the plant, completely eliminated the chlorosis and changed the leaves to a rich green color. Therefore, while we recognized that there are a number of physiological disturbances outwardly manifested by chlorosis, iron appeared to be the principal involved factor in the Pahala type.

Lee and McHargue (2) obtained evidence which led them to conclude that Pahala blight was caused by a deficiency of manganese. In view of this, and in view of the fact that we did not use extremely accurate methods in making our iron determinations and made no manganese determinations whatever, we decided to make analyses of cane leaves from our sulphur experiment at Pahala while such plants were available. This should give information regarding the effect of sulphur upon the composition of the cane plant. For comparative analyses we obtained other leaf samples from Pahala and some from other island districts. In making the analyses we used some very accurate colorometric methods developed by Hansson of this laboratory, and we believe the results are absolutely accurate. The following is a description of the samples: All samples represent the five youngest leaves upon the stalk, discarding the rolled or zero leaf. Each sample represents a composite of five leaves from five cane stalks.

The first three samples are from our sulphur experiment at Pahala in which a blight-susceptible variety, Yellow Bamboo, was grown.

1. Chlorotic leaves, crop cane, not a part of the experiment.
2. Chlorotic leaves, from check plot, received no sulphur.
3. Normally green leaves, no chlorosis, from sulphur plot.

The next three samples were taken from Field 21-B at Ewa Plantation. This is a coral field where cane is always severely chlorotic. An experiment was installed in the field, on the basis of Florida experiments where manganese sulphate gave excellent results as a corrective agent for chlorosis on high lime soils. All three samples were taken from a manganese-sulphate plot (150 pounds per acre). No response was obtained from the application of this material and cane in all stages of chlorosis was present in this plot.

4. Slightly chlorotic leaves, H 109.
5. Green leaves, H 109.
6. Severely chlorotic leaves, H 109.

In Lee's investigations he found evidence of manganese deficiency at Kilauea where cane will sometimes show a slight chlorosis. In view of this, and on the basis of some other observations at Kilauea, a rather extensive experiment was installed to determine the effect of manganese salts on cane. The two following samples were taken from this experiment. The cane is Yellow Tip variety and no chlorosis developed in the experiment.

7. Leaves from plot X, check plot, no manganese, no chlorosis.
8. Leaves from plot C, this plot received ½ ton per acre manganese sulphate, no chlorosis.

The next two samples are normally green Yellow Caledonia leaves, taken from the Experiment Station plots at Kailua, Oahu.

9. Normal Yellow Caledonia leaves, Kailua, Oahu.
10. Normal Yellow Caledonia leaves, Kailua, Oahu.

All the rest of the samples were taken at Pahala. The two from the Mudflow field represent normal Yellow Caledonia cane from a field that never develops chlorosis. The sample from Lower Stone field and the one from Lower Keaiwa field, non-chlorotic D 1135 cane, represent fields which produce chlorotic Yellow Caledonia.

11. Normal Yellow Caledonia leaves, Mudflow field.
12. Normal Yellow Caledonia leaves, Mudflow field.
13. Normal D 1135 leaves, Lower Stone field.
14. Normal D 1135 leaves, Lower Keaiwa field.

The following six samples were taken from a chlorotic area in Lower Whitney field for comparing chlorotic and non-chlorotic leaves from the same stool and from different stools:

15. Chlorotic leaves, Yellow Caledonia 16. Green leaves, Yellow Caledonia	from different stools.
17. Chlorotic leaves, Yellow Caledonia 18. Green leaves, Yellow Caledonia	growing in the same stool.
19. Chlorotic leaves, Yellow Caledonia 20. Green leaves, Yellow Caledonia	growing in the same stool.

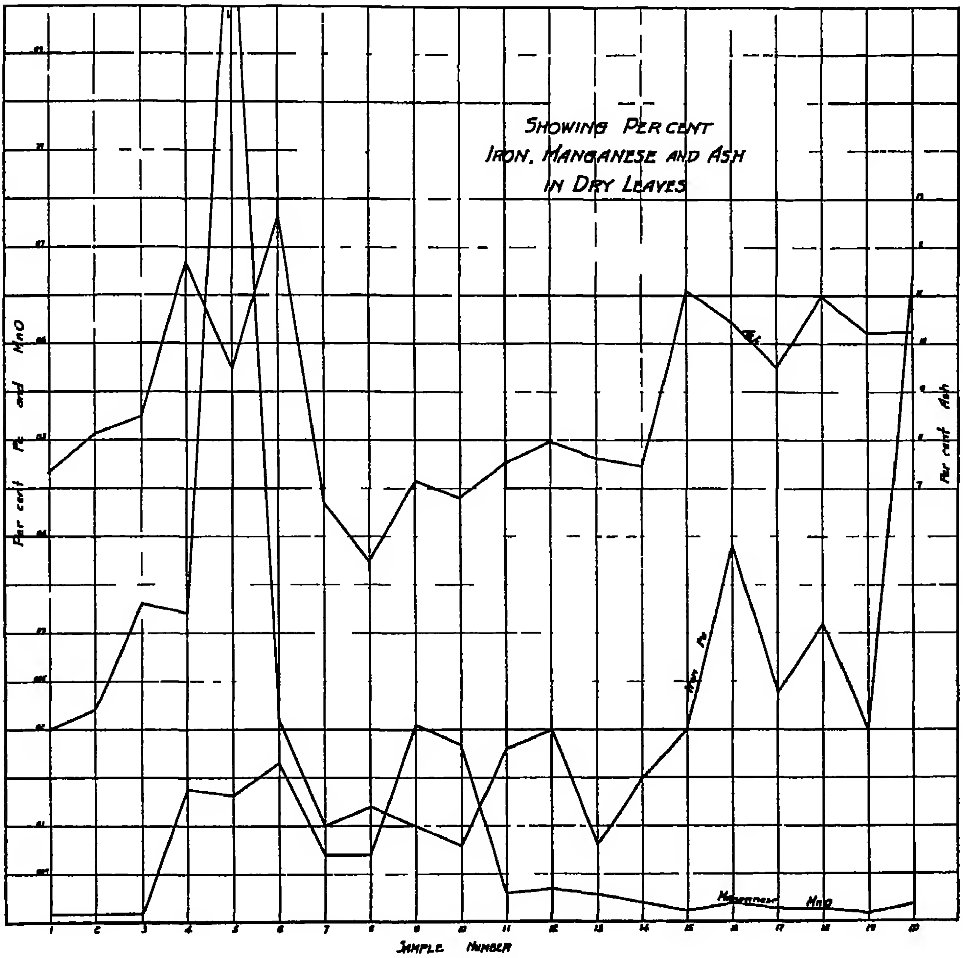

Showing Per cent
Iron, Manganese and Ash
in Dry Leaves
Per cent Fe and MnO
Per cent Ash
Sample Number

Fig. 1

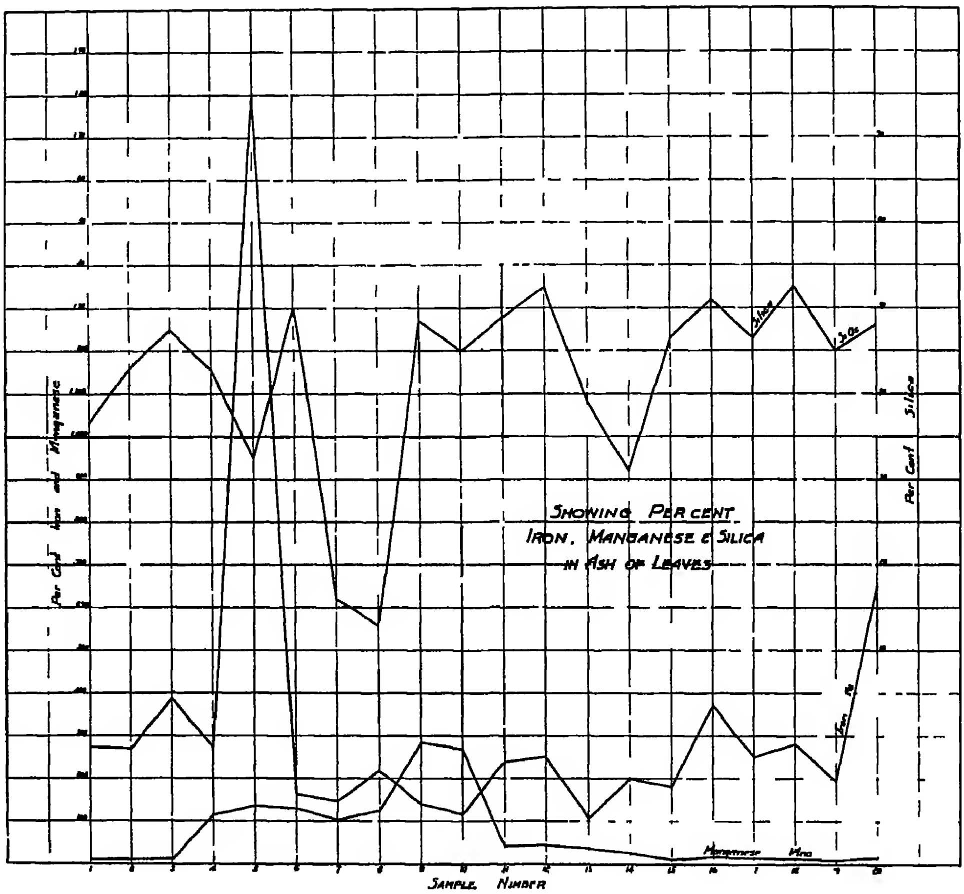

SHOWING PER CENT
IRON, MANGANESE & SILICA
IN ASH OF LEAVES
Per Cent Iron and Manganese
Per Cent Silica
Silica
SiO_2
Iron Fe
Manganese Mno
SAMPLE NUMBER

Fig. 2

The relative solubility of iron and manganese in Pahala soils was determined, using one per cent citric acid as a solvent. The results are given in Table II, but do not show any relation to the presence or absence of blight.

The analyses of the leaves are given in the following table and are shown graphically in Figs. 1 and 2:

TABLE I

Sample No.	Condition of leaves	Ash	Silica SiO_2	Calcium Ca	Manganese MnO	Iron Fe	Silica SiO_2	Calcium Ca	Manganese MnO	Iron Fe
			Per Cent Dry Matter				Per Cent Ash			
1	Chlorotic	7.33	2.69	.142	.0008	.020	36.7	1.93	.011	.273
2	Chlorotic	8.15	3.51	.122	.0009	.022	43.1	1.50	.011	.270
3	Green	8.51	4.04	.177	.0010	.033	47.5	2.08	.012	.388
4	Chlorotic	11.71	5.02	.218	.0137	.032	42.9	1.86	.117	.273
5	Green	9.47	3.08	.192	.0132	.171	32.5	2.03	.139	1.800
6	Chlorotic	12.68	6.34	.265	.0166	.021	50.0	2.09	.131	.165
7	Green	6.71	1.08	.614	.0070	.010	16.1	9.15	.104	.149
8	Green	5.50	0.71	.600	.0070	.012	12.9	10.90	.127	.218
9	Green	7.15	3.48	.244	.0204	.010	48.7	3.41	.285	.140
10	Green	6.82	3.06	.246	.0184	.008	44.9	3.61	.270	.117
11	Green	7.54	3.67	.214	.0031	.018	48.7	2.84	.041	.239
12	Green	7.97	4.18	.244	.0035	.020	52.4	3.06	.044	.251
13	Green	7.60	2.96	.174	.0029	.008	38.9	2.29	.038	.105
14	Green	7.46	2.31	.170	.0020	.015	31.0	2.28	.027	.201
15	Chlorotic	11.11	5.19	.402	.0012	.020	46.7	3.02	.011	.180
16	Green	10.46	5.35	.461	.0020	.039	51.1	4.41	.019	.373
17	Chlorotic	9.51	4.44	.389	.0014	.024	46.7	4.09	.015	.252
18	Green	11.00	5.80	.490	.0014	.031	52.7	4.45	.013	.282
19	Chlorotic	10.23	4.62	.436	.0010	.020	45.2	4.26	.010	.195
20	Green	10.28	4.95	.533	.0018	.067	48.1	5.18	.017	.651

TABLE II

Showing Per Cent Iron (Fe_2O_3) and Manganese (Mn_3O_4) in Pahala Soils Soluble in 1 Per Cent Citric Acid from Blight and No Blight Fields

Condition of Field	Iron Fe_2O_3	Manganese Mn_3O_4
Blight	0.88	.032
Blight	0.86	.041
No blight	0.42	.020
No blight	1.10	.017
Blight	0.76	.033
No blight	0.86	.032
Blight	0.46	.016
No blight	0.48	.011
Blight	0.76	.032
No blight	0.68	.065

Ash. The high ash in the leaves from Whitney field, a field noted for having been a bad blight field, tends to confirm our original opinion that a high ash reduces the mobility of the iron in the plant under Pahala conditions. The relative ash content of green and chlorotic leaves from Ewa Plantation is also significant in this connection, as representing a similar relation in limestone chlorosis.

Manganese and Iron. In the leaves taken from our experiment in Naahala field, the manganese has been increased only .0001 per cent (an 11 per cent increase), while the iron has been increased .012 per cent (a 57 per cent increase) by sulphur fertilization, which completely eliminated the chlorosis. On the basis of percentage in the ash, the increases are respectively .001 per cent MnO and .118 per cent Fe. In the Yellow Caledonia from Mudflow field, manganese is notably higher and iron slightly lower than in Naahala field, which is also true for the leaves from Stone and Keaiwa fields. Both of the latter are blight fields but were being cropped to D 1135 at the time leaf samples were taken. Samples 15 and 16 from Whitney field, leaves from different stools, show higher iron and manganese in the green leaves, but the manganese in the chlorotic leaves is still appreciably higher than in the green leaves from the sulphur experiment. In samples 17 and 18, both of which were taken from the same stool, there is no difference in the manganese but a much higher content of iron in the green leaves. In samples 19 and 20, which like 17 and 18 represent chlorotic and green leaves growing in the same stool, there is a higher manganese in the green but a 235 per cent greater iron. The leaves from Ewa, representing typical coral chlorosis, are all high in manganese, while the higher iron content of the green leaves is outstanding. The Yellow Tip leaves from Kilauea are notably high in manganese and low in iron, and there is no increase in the manganese content of the leaves from the manganese-sulphate application at the rate of 1,000 pounds per acre placed in the furrow near the seed. This soil is very low in manganese, while the Pahala soils are all well supplied with this element. The Yellow Caledonia leaves from Kailua are also high in manganese and low in iron. The Kailua area has just recently been changed from a rice field to cane, which probably accounts for the high availability of manganese.

The data show beyond question that cane grown at Pahala is low in manganese as compared with some other island districts, but there is very little difference in the green and chlorotic leaves and no increase from sulphur fertilization, which completely eliminates the chlorosis. On the other hand, there is a big difference in the iron content of the green and chlorotic leaves, with the former much higher than the latter, and this has been greatly increased by sulphur fertilization.

It is true that iron sulphate applied to the leaves at Pahala injures the tissues and that manganese sulphate dusts restore the green color of chlorotic leaves without injury. Further, in the large amount of work that has been done in the last few years upon the role of manganese in plant nutrition, it has been conclusively demonstrated that manganese has an important role in plant economy and that, like iron, it functions in large part as an aid to chlorophyl synthesis.

On the other hand, we have demonstrated in our work that chlorotic leaves under field conditions are characteristically high in ash, which may interfere with

mobility of iron or manganese, and that the soils in the blight fields are of a higher pH (1), which may lower the availability of iron in the soil. In addition, we have shown beyond question that the plants may be restored to normal green color and vigorous growth by increasing the acidity of the soil (1) (better availability of iron and manganese), and by increasing the acidity of the plant juice (1) with the aid of sulphuric acid injections into the cane stalk, which, too, would increase the mobility of iron within the plant. Finally, we have demonstrated that if iron sulphate is injected (1) into the stalk instead of being applied to the leaves where it burns the leaf tissue, there is a complete restoration of the cane to normal color and vigor.

The data which we have submitted in Table I lead us to believe that both iron and manganese are very necessary in chlorophyl synthesis, but that if one is absorbed by the plant in normal amounts a minimum absorption of the other will entirely satisfy the plant. This is indicated by the high iron and low manganese absorbed by cane growing on Pahala soils, and the high manganese and low iron absorbed by plants on the Kailua and Kilauea soils. In view of the fact that sulphur fertilization has not increased the absorption of manganese we are led to believe, on the basis of the large amounts of manganese absorbed on the other soils, that different soils may have rather definitely defined equilibrium concentrations for manganese. Further, in view of the fact that the effect of sulphur has shown itself in a greater assimilation of iron, and that the greatest difference in chlorotic and green leaves is in the iron content rather than the manganese content of the leaves, the results indicate that the iron deficiency and mobility is the greater economic factor in the type of chlorosis found at Pahala and usually called Pahala blight.

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Oriental Rice Borers and Their Parasites

By Fred C. Hadden

In March, 1928, the caterpillar of a moth was found destroying the stems of rice in the paddy fields at Honouliuli, Oahu. This moth is a pyralid, and has been definitely identified as *Chilo simplex* (Butler). The caterpillars chew their way up and down inside the rice stems, and stems thus bored turn brown, die and usually break and fall over, and no head of rice is produced on that stem. Notes on this rice borer were published by R. H. van Zwaluwenburg, E. W. Rust and J. S. Rosa in *The Hawaiian Planters' Record*, Vol. XXXII, No. 4, October, 1928, and the adult, pupae and larvae were figured.

Because this pest is one of the major rice pests in the Orient, and closely related to other moth borers which attack rice or sugar cane, it was thought highly advisable to undertake the introduction of parasites to control it in Hawaii. When first discovered, it was not known whether this insect would attack sugar cane, or whether it would develop a taste for cane in the future. Since the parasites of *Chilo* are not confined entirely to it, but also attack other rice and sugar cane moth borers, the establishment of *Chilo* parasites would not only aid the rice growers, but would also lessen the injury to cane by *Chilo simplex* if it should take to attacking cane, and be at the same time potential enemies of any cane moth borers that might accidentally become introduced into the Islands in the future.

A cooperative project was arranged in which D. T. Fullaway, of the Territorial Board of Agriculture and Forestry, and the writer, of the Experiment Station, H. S. P. A., were sent to the Orient in March, 1928, to investigate the natural enemies or parasites of *Chilo*, and to attempt their introduction to Hawaii.

This paper is an account of the work done in Japan, Formosa and China by Mr. Fullaway and the writer, and pertains to the methods of collecting, shipping, and rearing of *Chilo* parasites discovered in the Orient. On arriving in Japan, Mr. Fullaway stayed in Kobe, obtaining and shipping large numbers of egg-parasites during the first part of the year, while the writer proceeded on to Formosa in order to ascertain the status of the rice borer in relation to sugar cane, and to search for larval parasites. The entire west coast and part of the northeast coast of Formosa were covered in May and observations made in the extensive rice and sugar cane fields of that island. *Chilo simplex* caterpillars were found everywhere in rice, but never in sugar cane, although the cane fields were adjacent to badly infested rice. Following this, investigations were made in China. From a general casual observation of borer conditions throughout Japan, and in China along the coast from Hongkong to Shanghai, about 10 to 15 per cent of the entire Oriental rice crop is destroyed by rice borers.

However, *Chilo simplex* is not the only insect involved. There are two major moth borers in rice in Japan, and three in China; these in their order of importance are:

1. The "paddy borer" of Japan—*Schoenobius incertellus* Walker.
2. The "rice borer" of Hawaii—*Chilo simplex* (Butler).
3. *Nonagria inferens* Walker.

The adult insects are moths which do not do any damage to crops. The moths lay eggs. Tiny caterpillars hatch from these eggs; these are the rice borers and are what do the damage to the rice. They bite their way into the midribs of the leaves, bore down into the stems and kill the stalks. Stems thus bored turn yellow or brown, die and do not produce a head of rice. In some areas of a few acres each, in Foochow, China, over 80 per cent of the rice was destroyed. In these areas, parasites were scarce or were destroyed by hyperparasites.

Schoenobius incertellus is the "paddy borer" of Japan; it is also called Yaa, Tsuwyaa, Zuimushi and Itten-o-meichyu in Formosa and Japan. This insect has been reported as found in Ceylon, India, Burma, China, Java, Japan, Siam and the Philippines. It has been found attacking only rice by other entomologists, but the writer found larvae and pupae of this insect in Foochow, in rice, red rice and "gasung" (*Zizania aquatica* L.). The paddy borer is apparently the commonest and most destructive of the rice borers; it is extremely widespread, being found throughout the Oriental region. According to observations of the writer, *Schoenobius* was usually associated with *Chilo* and *Nonagria* in infested rice fields, but in some areas *Schoenobius* was doing nearly all the damage, as the other two borers were found extremely rare or not at all. This was also true of *Chilo*, for in some areas *Chilo* caterpillars were the predominant borers in the rice stems; the others were not found or were very scarce.

In parasite breeding work in Foochow, *Schoenobius* was not as highly parasitized as *Chilo*, in some cases less than one per cent being parasitized. This may indicate that the native home of *Schoenobius* is not around Foochow. The only parasite reared from *Schoenobius* boring in gasung was *Chelonus chilonis* Cushman.

Chilo simplex is the rice borer in Hawaii. It is a major rice pest in Japan, Formosa and China. It was found in numbers in southern Japan, Formosa and along the central coast of China from Shanghai to Hongkong. It was always more heavily parasitized than *Schoenobius*. This *Chilo* is the predominant rice borer in Taihoku, Formosa; in the south it is scarce. *Chilo* larvae were found most numerous in rice, rarely in red rice and *Zizania*. About twelve species of parasites were bred out of *Chilo* larvae in Foochow. Three species were sent to Honolulu in numbers and arrived alive and were liberated. These were *Amyosoma chilonis* Viereck, *Dioctes chilonis* Cushman, and *Centeterus alternecoloratus* Cushman. Other species were also shipped but arrived dead or too weak to be liberated. A few each of the other species were also liberated: *Cremastidea chinensis* Vier., Tachinids and *Chelonus chilonis* Cushm.

The life history of *Chilo simplex* is briefly as follows: The adult is a small, gray moth which lays masses of eggs in the spring on the young rice leaves of paddy growing in the seed beds, or in the fields. After the rice is a foot high the eggs are usually laid on the stems under the leafsheaths, or inside the leafsheath. There are 50 to 200 eggs in each mass or batch. The eggs are flat, oval disc-

shaped, and overlap each other like the shingles on a roof. They hatch in about a week. The young caterpillars or "rice borers" crawl and swim to other plants, but some bore into the leaves and stems of the plants the eggs are laid on. They bore into the midrib of the leaf, down the midrib and into the base of the stem. As many as fifteen or twenty small larvae have been found in one midrib of rice or *Zizania*. When first hatched the borers are very small, about one millimeter long, when full-grown about an inch long. They often migrate from one stem or plant to another one.

Chilo simplex overwinters in Foochow for four or five months in the rice straw (stems) as a full-grown caterpillar. There are three or four overlapping generations in the summer time.

In the summer, the length of time in the various stages is about:

Egg	6	days
Larva	30	"
Pupa	15	"
Adult	7	"
Total	58	"

In cooler weather, the life history is greatly prolonged. This is true especially of the full-grown larvae, which overwinter in this stage for five or six months. Thus the entire life cycle from the egg to the death of the adult may be from two to eight months.

Larvae could be found in the fields throughout the summer, but were small and difficult to find when the rice was small, that is, less than a foot high. Egg masses were not found around Foochow, although moths in cages were ovipositing readily.

Nonagria inferens Walker was found only in small numbers in rice and very rarely in red rice and *Zizania*. It is also found in Formosa.

Method of Procedure in Obtaining Rice Borer Parasites

Egg Parasites in Japan

Mr. Fullaway made his headquarters in Kobe in the Plant Inspection Building. Dr. C. Akiyama kindly loaned us the use of a large room in this building to use as a laboratory. In all our work in the Orient, Dr. Akiyama has been of the greatest assistance in transshipping material, in offering helpful suggestions, and in many other ways he has smoothed the path of difficulty for the foreign entomologists. Mr. Fullaway corresponded with many Japanese entomologists throughout Japan, and soon had collectors sending in *Chilo* eggs from many localities. These egg masses of 1 to 200 were wrapped in soft tissue paper in glass vials and pill boxes, kept in an ice box until just before the steamer left Kobe for Honolulu, then transferred as quickly as possible to the cool room of the Dollar and N. Y. K. steamship liners. A few days later the Experiment Station was sent a wire to meet that particular boat, and get the parasites. In Honolulu, Messrs. Rust and Van Zwaluwenburg received the material, bred the parasites through one or two generations and then liberated them in the fields. Many thousands of these parasites

were sent to Honolulu, a generation raised on Hawaiian *Chilo* eggs, and then liberated. In this way, hyperparasites were eliminated. Mr. Fullaway is to be complimented for the most satisfactory way the egg-parasite work was carried out. Messrs. Rust and Van Zwaluwenburg handled the material in a most satisfactory manner in Honolulu.

Two species of egg parasites were thus shipped:

1. *Phanurus beneficiens* (Zehnt.).
2. *Trichogramma japonicum* Ashm.

The latter is also known as the red-eyed trichogrammatid. In many cases 98 per cent of the eggs in a mass were destroyed by these parasites. The *Trichogramma* was established in Hawaiian rice fields as indicated by later recovery.

Larval Parasites

Ten species of insect parasites, a parasitic nematode, and a predaceous carabid beetle were found attacking *Chilo* larvae in Foochow. Ten to fifteen Chinese coolies were sent out into the rice fields and shown how to collect rice borer larvae. The dead and dying leaves and stems attacked by borers are easily seen, for they turn yellow or brown. They were cut off at the roots, the stem was then split up from the lower end until the borer was located, the stem was then cut off with a knife or scissors just in front of and behind the borer. These pieces were then brought in by the coolies, counted and paid for. Collectors were paid by the month or per piece of rice stem. Wages were $15.00 per month, or stems containing borers were bought at the rate of 5 for 1 cent. One of the favorite tricks of the collectors was to slip in stems not containing borers. Another was to collect for a few hours in localities where two or three borers were found in each rice stem, the rest of the day they sat under the shade of a tree transferring the borers to healthy stems so that they would get paid for each borer. A peculiar characteristic of these coolies was that they preferred to be crooked and lose money, to being honest and making more money. Perhaps the reason for this was that most of them came from a notorious pirate and bandit village.

Later on, the system was finally adopted of paying them 2 cents per parasite cocoon. Then they tried to substitute ant cocoons, which are quite similar to parasite cocoons. The greatest difficulty in working in the Orient is to get any one to do the thing you want him to do in the way you want it done.

The stems containing borers were kept in large glass jars 10 inches in diameter by a foot high, covered with cloth which was held on by rubber bands. Every day fresh pieces of *Zizania* were placed in the jars. The borers would crawl out of the older stems and bore into the fresh pieces. After a week or two adult parasites began to emerge, at the same time all kinds of other insects and hyperparasites would appear.

At times mites would breed in great numbers in the older decaying rice stems; they would fairly swarm over the parasites and in this manner would be carried to another place. Parasites thus attacked would try to scratch the mites off but were never successful in so doing, and as a result soon died. This made it necessary

to split open all the stems after a week has passed and to remove all parasite cocoons, and transfer them to new breeding jars; this successfully eliminated mites, although some of the parasites were killed due to too rough handling.

The adult parasites, after emergence, were fed honey and water and again transferred into clean, wide-mouth glass jars, which were stoppered with cotton, and placed in an ice box. It was necessary to personally conduct these up to Shanghai, because no one else could be trusted to give them the proper care. No matter how carefully written instructions are given something is always done wrong, and as a result the entire shipment arrives dead.

From the ice box in Foochow the parasites were rushed into the Chinese steamers anchored down the Min River at Pagoda anchorage, and into the ice box on the steamer. At Shanghai they were taken out, fed, transferred again to clean jars and put in the ice box in the Y. M. C. A. building. When the Dollar liner was about ready to sail to Honolulu, they were taken on board and put in the vegetable room at 40° F.

All the insects were kept from one to two weeks in Foochow before leaving on the Chinese steamer to Shanghai. They were kept in Shanghai from two to five days before leaving for Honolulu. The entire trip took from eighteen to twenty-four days, and the insects were always at least a month old (as adults) upon arrival in Honolulu.

The larval parasites arriving alive in Honolulu in fairly good condition were: *Amyosoma, Centeterus* and *Diocles*. Very few of the others arrived alive, except when personally conducted during the entire journey.

Parasite cocoons were also shipped. They were packed in 4-ounce tin salve boxes which were lined with soft tissue paper to absorb excess moisture and kept on ice at 40-50° F. throughout the trip, except for the short time (1/2 hour) it took to take them from the shore to the boat and the boat to the shore. The tins were put in thermos bottles to keep the temperature from changing, for, as soon as the cocoons warmed up, adults began to emerge in a few minutes. We now know that there is an overwintering period in which they stay in the cocoon in the cooler months; and that it is possible to ship them in the fall.

However, fall-shipped parasite cocoons are very heavily hyperparasitized by Chalcids, and only about 5 per cent of the true parasites emerge. The "hypers" come out by the hundreds, and great care must be taken to prevent their escape.

All foreign parasites received by the Station are handled in the quarantine room. This is a small room with a low ceiling, and finely screened windows.

Before entering this room it is necessary to pass through a small dark room, and two doors which are almost air-tight. The parasite cocoons are placed in large glass jars covered with cheesecloth. As the insects emerge, the true parasites are removed to new jars, and the "hypers" killed.

Emerging parasites were kept in jars to facilitate mating; some were kept to experiment with rearing in the laboratory, others were released in the fields.

Ichneumonid Parasites

The Ichneumonid parasites of rice borer larvae have a visible ovipositor. The manner in which they parasitize their host has not been definitely studied by the writer. They probably crawl around, up and down the rice stems until they locate a borer, they then pierce the stem with the ovipositor (or stinger) and either oviposit the egg inside the stem or penetrate the skin of the rice borer larva and lay the egg inside the body of the host. This must also be true of the Braconids with visible ovipositors or stingers. The parasites with visible ovipositors are:

Amyosoma chilonis Vier.
Dioctes chilonis Cushm.
Cremastidea chinensis Vier.
Amauromorpha schoenobiae (Vier.)

Chelonus chilonis Cushman is a braconid without a visible ovipositor. It probably parasitizes the host in the same manner as *Chelonus sonorensis* of Mexico. *C. sonorensis* inserts its eggs in the eggs of the rice borer and inside of the almost completely developed embryo. Later, the rice borer larva hatches from its egg and commences to eat and grow. In the meantime the *Chelonus* larva hatches and grows, living as a true internal parasite on the blood of the rice borer. It eventually kills the rice borer larva. This is a peculiar characteristic of nearly all parasites; they eventually kill or produce sterility in the host.

Tachinid Parasites

Only a few Tachinids (three species) were reared from rice borers. Their method of attacking the host is not known. They probably oviposit on migrating borers as they move from one stem to another. They are evidently not very effective parasites.

Carabid Beetles

Shortly after the rice harvest in Foochow a small black Carabid was found in small numbers in the rice stubble. Larvae, pupae and adults were found within the rice stems. In uncut rice fields the beetles were scarce. They were probably attracted into the fields from the surrounding country by the borers that were migrating from the stubble. Attempts to breed the beetles in cages were unsuccessful. They soon died in captivity.

Nematodes

At certain times nematodes killed and emerged from 20 to 50 per cent of the rice borer larvae. As many as five or six nematodes emerged from one caterpillar. Because it was thought that the nematodes would be detrimental to the insect parasites, no attempt was made to introduce them into Hawaii.

List of Parasites Studied

The following parasites were bred from rice borers or rice stems in the Orient:

1. *Amyosoma chilonis* Viereck
2. *Microbracon* sp.
3. *Shirakia schoenobiae* Vier
4. *Centeterus alterneecoloratus* Cushm
5. *Diocles chilonis* Cushman
6. *Chelonus chilonis* Cushm.
7. *Cremastidea chinensis* Vier.
8. *Amauromorpha schoenobiae* (Vier.)
9. *Goryphus basilaris* Hlgn
10. *Apanteles flavipes* Cam
11. *Apanteles chilocida* Vier.
12. *Apanteles* sp
13. *Trichogramma japonicum* Ashm.
14. *Phanurus beneficiens* (Zehnt.)
15. A gray Tachinid fly (Sp K.)
16. A black Tachinid fly (Sp. J.)
17. A predaceous black carabid beetle (Sp. L.)
18. A nematode worm.

Some of these parasites were liberated on Oahu in the following numbers:

Amyosoma chilonis about	250
Centeterus about	40
Diocles about	30
Cremastidea about	8
Microbracon sp. about	8
Sp. "K" about	6
Sp. "J" about	2

Hyperparasites

Four or five species of chalcids were reared from parasite cocoons. also two or hree species of small hymenopters not chalcids.

Mr. Fullaway* lists parasites released in 1928 as follows:

Egg Parasites:

Trichogramma japonicum	41,975
Phanurus beneficens	37,965

Report of the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii for the Biennial Period ended December 31, 1928, p. 46.

Larval Parasites:

Japanese Amyosoma	212
Japanese Apanteles	289
Centeterus alternecoloratus	40
Dioctes chilonis	141
Amyosoma chilonis	86
Cremastides chinensis	20

Thus a total of about 80,000 egg-parasites, and about 900 larval parasites on the rice borer have been liberated in Hawaii at different times in the following localities: Honouliuli, Kaneohe, Pearl City Road, Waialua and Honolulu on Oahu; also at Nawiliwili, Kauai.

Amyosoma chilonis Vier. was reared for liberation in the summer of 1929.

It is now definitely known that the following parasites have become established:

Trichogramma japonicum
Dioctes chilonis
Amyosoma chilonis

They have been recovered in Hawaiian rice fields in the summer and fall months of 1929. Mr. Fullaway says in the Report of the Entomologist for the week ended November 30, 1929, Board of Agriculture and Forestry: "Two of the larval parasites (of rice borer) were recovered from the field during the week confirming their establishment. They are *Dioctes chilonis* and *Amyosoma chilonis*."

Some Effects of Molasses Fertilization

By W. T. McGeorge

During the last few years considerable interest has been manifested regarding molasses fertilization on our plantations. On the basis of some early soil investigations and observations, in spite of the high potassium content of the molasses, its application to fields had been scrupulously avoided for fear of injuring cane growth. It now appears that the prejudice against molasses had been largely based upon a misunderstanding of its effects upon the soil under field conditions. Laboratory studies rather than field studies had been the basis of most conclusions. During the past two years we have obtained further information upon the problem, which is of interest.

It is largely to the credit of W. W. G. Moir that the question of molasses fertilization has been reopened, and this has undoubtedly led to a better understanding of the problem. Excellent reviews of the literature, with comments by plantation field men, have been published by Mr. Moir*, so these will not be repeated here.

A part of the investigations reported in this paper were taken up at the solicitation of W. P. Alexander, formerly head of the department of research and control at Ewa Plantation Company, and the rest as a part of a study of the fertility of Kilauea Sugar Plantation Company soils. In the former, we were interested in the conditions under which molasses injured cane growth, as contrasted with other fields in which notable response to molasses was being obtained. In the latter, we were interested in its relation to the availability of potassium and its effect upon the soil colloids. A highly dispersed soil colloid was believed to be associated with the poor fertility of Kilauea soils.

The Causes of Injury

Iron and Aluminum: It has been found that when molasses is applied to growing cane few or many spots may appear in the field in which the leaves turn yellow or, in severe cases, will die. We have obtained some rather definite evidence of the cause of this injury. On close examination of the plants the leaves appeared to have been injured by toxic amounts of iron and aluminum, and this was confirmed by comparative analyses of the cane which showed a greater amount of these elements in the injured cane as compared to normal cane growing near by. This was further confirmed by an examination of the soil. The soil was a heavy clay type, and in the areas where injury occurred drainage was very poor. In some areas, standing water was still present in the furrows. There was a film of iron rust on the surface of the water and soil in the poorly drained areas. This

* Presented at forty-eighth annual meeting of the Hawaiian Sugar Planters' Association, December, 1928.

was caused by the solvent effect of the fermentation products of molasses, the acids, upon iron and aluminum compounds of the soil. The iron had subsequently precipitated as ferric hydroxide or carbonate on contact with the air. Qualitative tests for iron and aluminum accumulations at the nodes of the cane stalk also gave evidence of toxicity from these elements. We therefore believe that iron and aluminum salts are the principal cause of injury from molasses, and that this will only occur in poorly drained soils where the molasses is allowed to accumulate and to ferment under anaerobic conditions. In well drained soils it would be the better policy to apply lime with molasses if the "active" aluminum content of the soil is high.

Nitrites: We were surprised to learn on examining the soils from the areas at Ewa Plantation that larger amounts of nitrite nitrogen were present in the soils where the cane had been injured, while there was no difference in the amount of nitrate, both showing only traces of this form of nitrogen. The soil, where no injury to cane had followed molasses treatment, contained no nitrite, while that from the injured area contained .55 part per million of dry soil. All organic or ammonia nitrogen must, during the process of nitrification, pass from ammonia to nitrite before being changed to nitrate. The change is, however, very rapid and only traces of nitrite are found in soils except where oxygen is deficient, as the latter is vital to the final step in nitrification. Having no information on the effect of nitrite nitrogen upon sugar cane, some experiments were conducted in order to determine this.

Four pots of 50 pounds capacity were filled with Experiment Station soil and four with silica sand. Each pot was planted with three-eye H 109 seed. Once each week nitrogen was added to two of the sand pots and to two of the pots of soil at the rate of 0.1 gram nitrogen from sodium nitrite. To the other four pots the same amount of nitrogen from sodium nitrate was added. Potassium phosphate was added to each of the sand pots to supply these two elements. The plants were grown from December 29, 1928, to March 23, 1929, and at no time was there any toxic effect from the sodium nitrite. At the completion of the experiment the sand and the soil from the pots were analyzed and the nitrate and nitrite present in dry soil or sand are given in the following table:

	P. P. M. as Nitrate	P. P. M. as Nitrite
Sand—nitrite nitrogen	5.2	.13
Soil—nitrite nitrogen	40.3	1.00
Sand—nitrate nitrogen	4.8	.06
Soil—nitrate nitrogen	40.3	1.34

The soil from the molasses injured cane at Ewa contained .55 p.p.m. nitrite nitrogen, so it hardly seems possible that nitrite was associated with the injury.

Nitrogen Availability

In the main, controversy over the value of molasses has involved its relation to soil nitrogen and the activities of soil organisms associated with nitrogen transformations within the soil confines. It has been the general belief that denitrifica-

tion follows molasses fertilization. In order to study some of these factors, Mr. Alexander installed an experiment and placed it at our disposal. It was located in Field 17B, Ewa Plantation Company, and consisted of sixteen plots; four of these were molasses plots; five were check plots; and seven were buffer plots separating the check plots from the molasses plots. The soil is a red clay loam. The area is a gently sloping one with good drainage in the upper plots, 1 to 13, merging into a heavier soil, less well drained in the lower plots, 14 to 16. It was hoped that drainage was sufficiently poor in the latter to cause injury. The cane was H 109 ratoons. The previous crop had been harvested August 28, 1928, to September 1, 1928. Molasses was applied at the rate of 17.6 tons per acre on September 17, in the first irrigation water.

Four plots were chosen for study, namely, 9 and 16 for the check plots and 11 and 14 for the molasses plots. The first set of samples was taken on September 17, just before the molasses was applied. At this sampling both the first and second foot of soil were sampled for future use in case injury should develop. The second set of samples was taken, representing the first foot only, September 26, just 9 days after the molasses had been applied. The third set was taken on November 20, the fourth on January 9, the fifth on January 25, and the sixth on March 6.

Data obtained from these samples included moisture and nitrate content under field conditions, *in situ*, and nitrate formed by incubating the soils in the laboratory. Soil reaction was determined for the first two sets of samples, and in a number of cases nitrite nitrogen was determined. The nitrate formed by incubation or the nitrifying power of the soil was determined by incubating 100 grams of soil for 28 days, at optimum moisture content, in the laboratory. The data obtained are given in the following tables:

TABLE I

September 17

Showing Moisture Reaction, Nitrate, and Nitrite Content of Soil *In Situ* and Nitrifying Power. All Except Moisture Are on Dry Basis.

Plot		Per Cent H_2O	pH	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrite in Soil	p. p. m. N as Nitrate † Formed by Incubation
9a*	Check plot	13.8	7.6	2.6	.019	6.1
9b		15.9	7.3	2.6	.009	6.3
11a	Molasses plot	14.7	7.6	2.6	.011	6.2
11b		15.5	7.4	3.0	.005	5.8
14a	Molasses plot	17.7	7.7	4.6	.006	6.8
14b		18.4	7.5	3.3	.007	6.0
16a	Check plot	17.2	7.6	4.6	.012	10.4
16b		18.7	7.4	2.7	.009	7.3

*a—soil; b—subsoil.

†Corrected for nitrate originally in soil. This is true of all the nitrifying power data given in this report.

TABLE II

September 26

Showing Moisture, Reaction, Nitrate, and Nitrite Content of soil *In Situ* and Nitrifying Power. As in Table I, on Dry Basis.

Plot		Per Cent H_2O	pH	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrite in Soil	p. p. m. N as Nitrate Formed by Incubation
9	Check plot	21.6	7.6	2.8	.130	4.6
11	Molasses plot	21.6	7.6	2.8	.070	6.1
13	Check plot	20.8	7.4	2.8	.000	3.2
14	Molasses plot	26.0	7.4	tr	.070	8.1
16	Check plot	25.2	7.4	5 9	.010	3.7

TABLE III

November 20

Showing Moisture, and Nitrate Content of Soil *In Situ* and Nitrifying Power, Dry Basis.

Plot		Per Cent H_2O	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrate Formed by Incubation
9	Check	18.0	9.3	4.5
11	Molasses	19.4	12.8	12.2
14	Molasses	22.8	66.8	23.2
16	Check	21.4	34.8	tr

TABLE IV

January 9

Showing Moisture and Nitrate Content of Soil *In Situ*, Dry Basis.

Plot		Per Cent H_2O	p. p. m. N as Nitrate in Soil
9	Check	24	17.4
11	Molasses	24	24.6
14	Molasses	25	23.2
16	Check	24	21.7

TABLE V

Showing Moisture, Nitrate and Nitrifying Power, Dry Basis

Plot		Per Cent H_2O	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrate by Incubation
9	Check	24	52	7
11	Molasses	24	52	14
14	Molasses	25	51	— 7
16	Check	25	146	—61

TABLE VI

March 6

Showing Moisture, Reaction, Nitrate Content of Soil *In Situ* and Nitrifying Power, Dry Basis.

Plot		Per Cent H_2O	pH	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrate Formed by Incubation
9—1	Check	18	8.0	3.9	8.3
9—2	Check	22		4.2	6.6
9—2	Check	18		3 9	6.9
11—1	Molasses	16	8.0	15.8	11.4
11—2	Molasses	19		15 9	48.6
11—2	Molasses	18		16.3	16.0
14—1	Molasses	24	7.7	8.6	11.6
14—2	Molasses	22		8.3	20.4
14—2	Molasses	24		10.8	21.4
16—1	Check	22	7.7	7.2	5.6
16—2	Check	22		10.5	16.9
16—2	Check	24		17.8	3.7

Plots 9 and 11 are in the better drained, higher level of the experiment, while 14 and 16 are in the heavy soil at a lower level than 9 and 11. All the determinations were made upon the fresh soil direct from the field and are calculated to a common basis of water-free soil.

Table I: There is little variation in soil reaction but slightly higher nitrate nitrogen in the lower area, plots 14 and 16, as well as better nitrifying power. It is evident from column one that this higher nitrate and better nitrifying power are associated with a better moisture-holding capacity. So much for the soil properties before molasses fertilization.

Table II: This set of samples was taken September 26, 9 days after the molasses was applied, and an additional check plot, No. 13, was included. The change in soil reaction is practically nil on this soil type and no apparent injury to cane growth was visible. The higher moisture-holding capacity of plots 14 and 16 is again in evidence. The incubation tests show a better nitrifying power in the molasses plots, even at this early date. This indicates that if denitrification processes are active the nitrifying power has been sufficiently increased to more than make up for any loss of nitrate under field conditions. There was no evidence of nitrogen starvation in any of the plots at this period.

Table III: The third set of samples was taken two months after the application of the molasses and shows a great increase in nitrate content *in situ*, as well as an increase in nitrifying power of the soil in the molasses plots. Plots 14 and 16,

1—Sampled with soil augur, 12 inches.
2—Sampled with soil trowel, 6 inches.

with better water-holding capacity, still show higher nitrate, and the cane was making better growth at this time than in plots 9 and 11.

Tables IV and V: On January 9 this field had just been irrigated and the samples obtained with the soil auger were so badly puddled that weighing a representative sample for nitrification was impossible without first drying the soil. Therefore, only nitrate *in situ* was determined. Unfortunately, the January 25 sampling was also made just at the time of irrigation as well as fertilization. The samples taken were in a badly puddled condition and as drying in the air, which would have been necessary to get a representative sample, was out of the question, the results cannot be accepted as accurate. The fertilizer had just been applied and this necessarily entails incomplete diffusion within the soil confines.

Table VI: After the experiences of January 9 and 25, the next sampling date was set for the day preceding the first March irrigation, i.e., March 6. At this time the soil was in an excellent physical condition. Three samples were taken from each of the four plots; one with a soil auger, five borings one foot in depth, and two with a trowel, each from eight spots to a depth of six inches. The soil still continues to show higher nitrate nitrogen in the molasses plots and better nitrifying power. Of the two check plots, better availability of nitrogen continues to prevail in plot 16 where the moisture-holding capacity is higher. At this date there appeared to be a noticeable response to molasses in plot 11, as compared to check plot 9. But there is no observable difference between plots 14 and 16 where the water-holding capacity is higher, and nitrification in the check plot 16 is very good. Cane growth is very good in both plots 14 and 16. The samples taken with a trowel show considerable variation, which indicates less uniformity in the surface 6 inches of soil.

Judging from the preceding, there is no evidence of denitrification but rather a stimulation in nitrification and nitrifying power from the time immediately following that at which the molasses was applied. In order to compare soil from this experiment with that from other fields at Ewa, to which molasses had been applied, soil samples were taken from a number of other fields.

Field 15B: This field received 11¼ tons per acre of molasses July 3 to July 5, 1928. New ratoons were starting just at that time. At first there was a temporary injury which manifested itself in the form of pale green leaves. This injury was not uniform, but was present only in scattered spots and the cane soon grew out of it, after which an excellent response to molasses, as compared to the check plots, appeared. This experiment included a number of plots to which potash had been added in amounts equal to that added in the molasses in order to compensate for this factor. Soil samples were taken September 26, 1928, from check plot 4, molasses plot 3, and a potash plot.

Field 2A: This field received 18 tons per acre molasses May 19 to June 9, 1928, and the soil samples were taken September 26, 1928, 4 months after application, from adjacent molasses and check plots. The cane was showing excellent response to molasses in this field at the time of sampling.

Field 21B: This field received 7¾ tons molasses per acre April 10 to June 11, 1927, and the soil samples were taken November 20, 1928. At this time the ex-

periment was in its second crop. The crop to which the molasses was added had shown no response to the treatment. This is a coral-impregnated field in which the cane is afflicted with limestone chlorosis, and the molasses had been added in order to observe its effect upon chlorosis. This is the only field sampled which had not shown response to molasses.

Field 13C: This field received 28 tons molasses per acre on June 16 to June 21, 1928, and the soil samples were taken November 20, 1928. During the early growth there was some injury, which appeared in small spots, but the cane soon grew out of it and from that period appeared to be making better growth where the molasses had been applied. It is probable that 28 tons is too large an application for this field.

These soil samples were analyzed for moisture and nitrogen, and their nitrifying power determined with the results as given in the following table:

TABLE VII

Showing Moisture, Nitrate Nitrogen and Nitrifying Power of Soils

	Per Cent H_2O	p. p. m. N as Nitrate in Soil	p. p. m. N as Nitrate Formed by Incubation
Field 15B—Potash plot	27	5.9	6.3
Field 15B—Check plot	22	4.3	4.9
Field 15B—Molasses plot	28	3.0	27.6
Field 2A—Check plot	21	18.0	12.0
Field 2A—Molasses plot	17	11.4	14.6
Field 21B—Check plot 59X	25	5.9	7.6
Field 21B—Molasses plot 60M	27	16.4	18.6
Field 21B—Molasses plot 64M	28	8.6	23.1
Field 21B—Check plot 65X	25	3.6	7.5
Field 13C—Check plot	25	3.6	6.9
Field 13C—Molasses plot	26	3.6	17.8

These data tend to confirm the results obtained in our soil studies on the experiment in Field 17B. In every case the better nitrifying power of the soil from the molasses plots, which signifies a greater availability of soil nitrogen, is shown. It is significant that this property is still manifested in Field 21B 18 months after the molasses had been applied. The greener color of the cane leaves growing on the molasses plots further testifies to the better nitrogen availability. The greater difference in nitrifying power, as compared to the difference in nitrate present in the field, testifies to the fact that the cane was using this extra nitrogen as fast as it was being nitrified.

Availability of Potash and Phosphate

Moir found a distinct increase in available potassium and phosphate in the soil following molasses fertilization at Pioneer Mill Company after one year, with a

still greater increase after 5 years. At Ewa we did not find any effect upon phosphate availability, but found that the potassium from molasses had greatly enriched the supply of available potassium in the soil.

The availability of potash and phosphate, as measured by one per cent citric acid, is given in Table VIII, and for two fields the solubility of potassium in water saturated with carbon dioxide is given in Table IX. The data do not show any definite relation to phosphate availability, but in every case the citric soluble potash is greatly increased, except in Field 21B and it is significant that this is the only field in which no response to molasses was obtained. The molasses application in this case was the smallest, 7¼ tons per acre, and the soil differs in being a coral type, which may have influenced the availability of potash. The data in Table IX also show a greater solubility of potassium in water saturated with carbon dioxide, and this is significant in that plant roots feed largely by the aid of carbon dioxide which they secrete. These data show beyond question that potash added in molasses is fixed by the soil in a highly available form.

TABLE VIII

Showing Per Cent K_2O and P_2O_5 Soluble in 1 Per Cent Citric Acid.

Sample and Field	K_2O	P_2O_5
15B—Potash plot	.033	.0213
15B—Check plot	.023	.0190
15B—Molasses plot	.059	.0193
2A—Check plot	.021	.0093
2A—Molasses plot	.052	.0098
21B—Check plot, 59X	.029	....
21B—Molasses plot, 60M	.025	.0293
21B—Molasses plot, 64M	.025	.0102
21B—Check plot, 65X	.016	.0041
13C—Check plot	.026	.0285
13C—Molasses plot	.043	.0285
17B—Check plot, 9X	.011	.0070
17B—Molasses plot, 11M	.042	....
17B—Molasses plot, 14M	.066	.0137
17B—Check plot, 16X	.021	.0300
(September 26 samples.)		

TABLE IX

Showing Per Cent K_2O Soluble in Water Saturated With Carbon Dioxide.

Sample and Field	K_2O
15B—Check plot	.008
15B—Molasses plot	.026
2A—Check plot	.006
2A—Molasses plot	.021

Molasses as an Amendment for Infertile Soils

At Kilauea Sugar Plantation Company, where the soils are very infertile, it is the practise to fallow the fields for a period between the last ratoon and replanting. The value of such a program is usually reflected in a better yield of plant crop and a lack of response to nitrogen. The increase in available nitrogen, due to better aeration, sunlight, etc., is sufficient to supply the requirement of the plant crop. From our observations, there is much in similarity between the effect of molasses on our soils and that of aeration and fallow. Our virgin soils usually show very little nitrifying power but this is greatly increased by plowing. A similar condition also exists in poorly aerated cultivated soils which have become matted and shaded by the heavy growth of cane for some months preceding harvest.

In view of the above, the question naturally arises, will plantation soils which apparently demand a period of fallow respond to molasses, and can molasses fertilization replace fallow in the crop cycle? Kilauea Plantation soils are excellently suited for such an investigation, and in our study of molasses fertilization this phase of the problem has been included and much information has been obtained.

Five different series of pot experiments, involving 100 pots in all, each pot holding 55 pounds of soil, were conducted in this study. The soil selected for this work was taken from Field 24, Kilauea Sugar Plantation Company, a poor field, and in view of the fact that Kilauea soils are highly colloidal and underlain with a very toxic subsoil, which is undoubtedly one factor which makes a fallow necessary, this subsoil was included by using soil 18 to 24 inches. In every case, we obtained better plant growth when complete fertilizer was supplemented by molasses. In every case we obtained better plant growth on aerated soil, as compared with soil which was transferred from the field to the pots without permitting aeration. In the unaerated toxic soil and subsoil no response was obtained with heavy applications of complete fertilizer, except where molasses was also applied. In fact it was evident throughout these experiments that the effect of molasses was quite similar to aeration.

As a matter of interest, two of these experiments are explained in detail:

Experiment D: The soil used in this series had been used in other pot experiments here at the Experiment Station and, while not allowed to thoroughly dry, had been well aerated and had received some previous fertilization.

Experiment E: The soil used in this experiment was taken from the same spot in the field as that used in Experiment D, but was placed directly in the pots without permitting any aeration.

The plan of these experiments was as follows: All pots contained the same weight of soil, 55 pounds; were planted to Yellow Tip seed; were planted on the same day, April 1, 1929; and fertilized on the same day, March 29, just one day preceding planting. Numbers represent grams added of dried blood and nitrate of soda (N), sulphate of potash (K), superphosphate (P), molasses (Mol.) and sugar.

EXPERIMENT D

1. N7
2. N7—Mol. 300
3. N7—Sugar 300
4. N7—Sugar 300—K25
5. N7—K25—P25
6. N7—K25—P25—Mol. 300
7. N7—K25—P25—Sugar 300
8. N7—K25—P25—Sugar 300—K25

EXPERIMENT E

1. N7
2. N7—K25—P25
3. N7—K25—P25—Mol. 300
4. N7—K25—P25—Sugar 300
5. N7—K25—P25—Sugar 300—K25
6. N7—P25—Sugar 300

We sought, in this experiment, information on the effect of aeration on cane growth, the comparative effect of complete fertilizer on aerated and unaerated soil with and without molasses, and the relative influence of the sugar and potassium, in molasses, upon the response obtained.

Growth measurements were made at intervals during the growth of the plants, and these are given graphically in Figs. 1 and 2, together with the final weight of tops and roots. The tops were analyzed and the comparative composition is given in Tables X and XI.

TABLE X

Showing Composition of Plants Grown in Experiment D

Treatment	Nitrogen N	Ash	Silica SiO_2	Phosphate P_2O_5	Calcium Ca	Magnesium Mg	Potassium K
			Per Cent Dry Matter				
1. N	.587	5.25	1.48	.383	.225	.131	1.48
2. N—Mol.	.602	6.31	1.11	.337	.220	.102	2.22
3. N—Sugar	.531	5.90	1.83	.339	.248	.153	1.51
4. N—Sugar—K	.546	6.76	1.43	.345	.116	.071	2.37
5. N—K—P	.514	7.37	1.45	.378	.139	.076	2.56
6. N—K—P—Mol.	.537	7.26	1.25	.381	.133	.082	2.58
7. N—K—P—Sugar	.495	6.58	1.30	.429	.136	.085	2.37
8. N—K—P—Sugar—K	.458	7.05	1.63	.423	.165	.105	2.52
			Per Cent Ash				
1.			21.9	7.30	4.29	2.49	28.3
2.			17.6	5.35	3.52	1.61	35.3
3.			31.0	5.74	4.22	2.60	25.6
4.			21.1	5.09	1.71	1.05	35.2
5.			19.7	5.13	1.90	1.03	34.8
6.			17.3	5.24	1.81	1.13	35.6
7.			20.0	6.51	2.06	1.30	36.1
8.			23.0	6.00	2.33	1.49	35.8

* Analyses by J. H. Duffy.

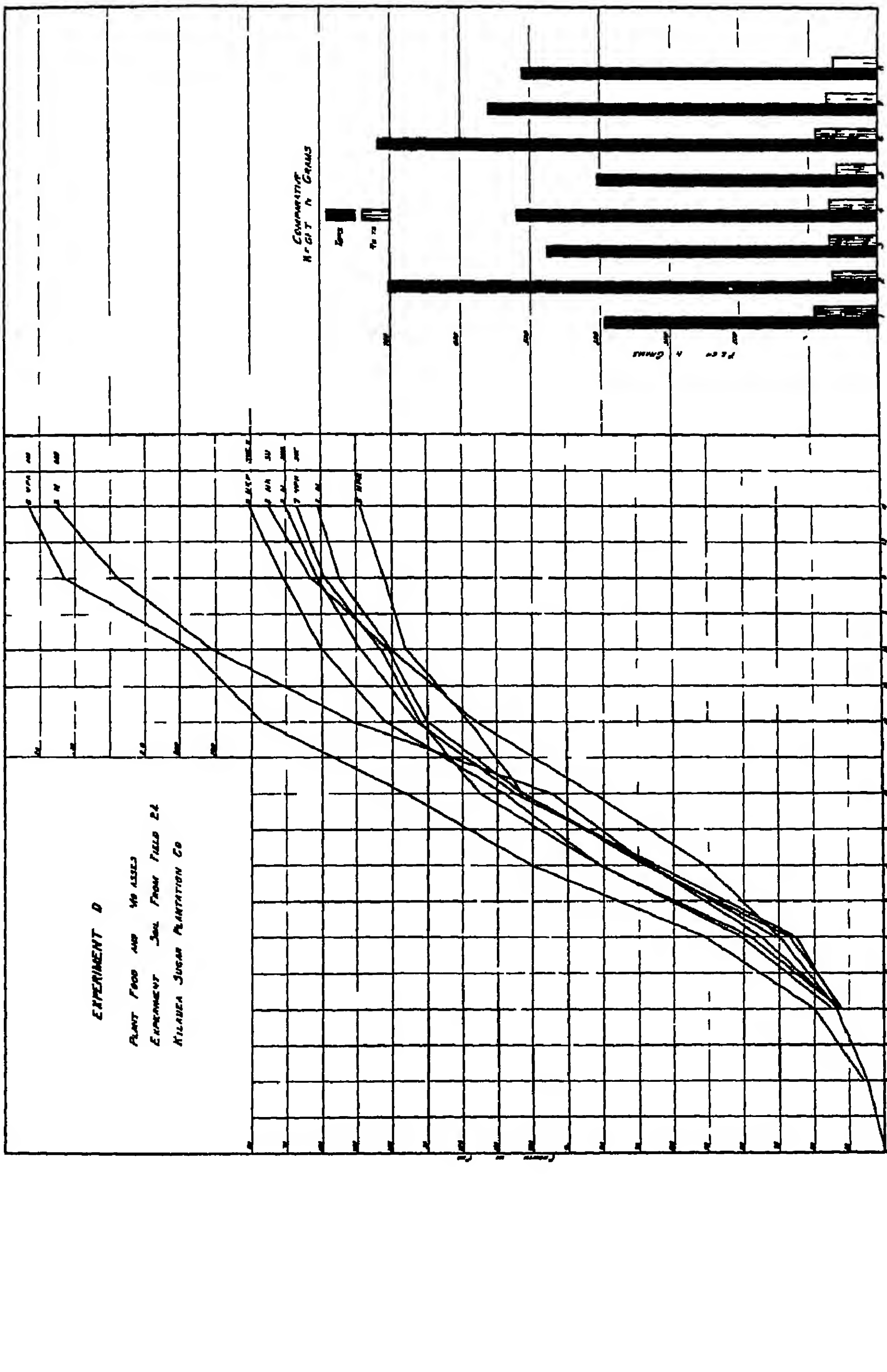
EXPERIMENT D
Plant Food and Molasses
Experiment Soil From Field 24
Kilauea Sugar Plantation Co

Fig. 1

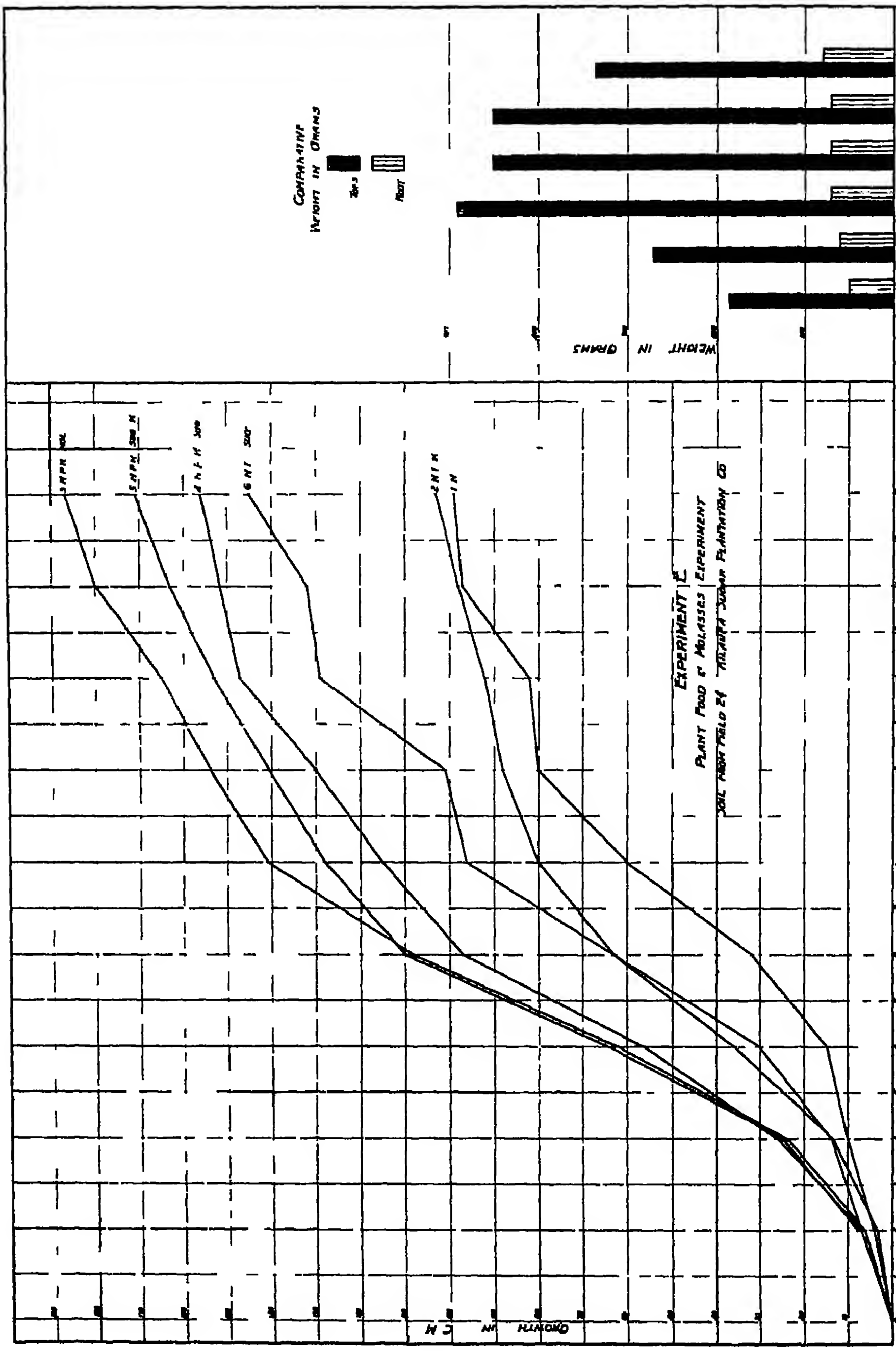
Comparative Weight in Grams
Tops
Root
Weight in Grams
Growth in C M
Time in Weeks
Experiment E
Plant Food & Molasses Experiment

Fig. 2

TABLE XI

Showing Composition of Plants Grown in Experiment E*

Treatment	Nitrogen N	Ash	Silica SiO_2	Phosphate P_2O_5	Calcium Ca	Magnesium Mg	Potassium K
			Per Cent Dry Matter				
1. N	.456	4.17	.82	.300	.384	.267	.86
2. N—P—K	.411	6.20	.60	.340	.146	.088	2.13
3. N—P—K—Mol.	.412	5.55	.43	.321	.168	.108	2.20
4. N—P—K—Sugar	.433	5.56	.59	.392	.157	.087	2.07
5. N—P—K—Sugar—K	.493	6.12	.97	.581	.174	.112	2.42
6. N—P—Sugar	.525	3.96	.50	.245	.385	.348	.65
			Per Cent Ash				
1.			19.7	6.70	1.97	6.39	20.77
2.			10.5	5.98	2.56	1.55	37.47
3.			9.4	5.78	3.03	1.94	39.57
4.			10.6	7.04	2.83	1.56	37.17
5.			15.9	9.48	2.84	1.82	39.53
6.			12.7	6.18	9.72	8.78	16.44

Figs. 1 and 2 show a notable response to sugar (sugar was added as syrup of the same Brix as that of the molasses), but a still greater response to molasses in both experiments. This is reflected in a greater weight of tops in both, and a much greater weight of roots in the unaerated soil treated with molasses. This effect of molasses and sugar upon the production of roots in this toxic soil is especially significant. There is a notable lack of response to nitrogen, potash and phosphate as compared to nitrogen only, the growth being very poor in the unaerated soil but very good in the aerated soil. Where additional potash is added with sugar to make up for that present in molasses, the response is still less than that obtained with molasses. The response to molasses in the unaerated soil, while better than that obtained without molasses in the aerated soil, is not so great as that obtained with molasses on the aerated soil. It is to be regretted that we did not include in this series a treatment of coral rock with molasses, as we have evidence that the molasses is more effective on this soil type if lime also is added.

The plant analyses show a better assimilation of nitrogen from the aerated soil as compared to the unaerated. While there is some variation in nitrogen in the different treatments, it can not be stated that any of these have greatly affected the nitrogen as per cent dry matter, but of course in amounts of nitrogen actually assimilated, the larger plants, that is, those fertilized with molasses, have assimilated the greater amount. The same is true for the assimilation of potassium and phosphate. In fact, so far as the chemical composition of the plants is concerned, the analyses do not indicate that the relative composition is materially altered by molasses fertilization. The amount of potassium assimilated is especially significant in this connection as just as much potassium has been assimilated from potassium sulphate as from molasses. It is evident from these experiments that the

*Analyses by J. H. Duffy.

potash present in molasses is not the cause of the improved growth on this soil, although this element will be supplied by molasses in an extremely available form.

The toxicity of soils, such as we have used in these experiments, has largely developed from poor aeration, a condition which always accompanies an excess of highly colloidal clay, if associated factors are such as to induce a highly dispersed state On exposing such soils to the air, to sunlight, or other environment which tends to correct the effect of this lack of aeration, there will follow an improvement in fertility of the soil. Together with this improved fertility, there is an improvement in the physical condition of the soil. The clay will appear less dispersed, will settle more readily when shaken in a column of water, and will, in the field, appear more granular or shotty. One of the principal agents involved in this change in soil property is the carbon dioxide in the air, which, of itself and as basic bicarbonates, is an active flocculant for clay. Accompanying this more desirable physical state is a better availability of plant food and a more active biological flora.

In the fermentation of sugar, copious amounts of carbon dioxide are produced, and we have found that this, like the carbon dioxide of the air, works for a more favorable mechanical state in the soil. This is especially true if there is sufficient calcium in the soil to combine with carbon dioxide to form calcium bicarbonate, which is an active flocculant. Applications of calcium carbonate and molasses to heavy clay soils should be effective if provision is made for proper aeration during the period of active fermentation. Our experiments demonstrate that the effect of molasses is largely reflected in a better root system, and this in turn is the result of an environment created by molasses fermentation, conducive of more active root respiration. The relative composition of the plant is not greatly altered by molasses fertilization as compared to applications of complete fertilizer. It is simply a case of larger amounts of plant food being assimilated through a more active root respiration, and therefore a greater production of plant material. In other words, molasses acts toward the soil in many ways like a fallow, by stimulating nitrification, improving the physical condition and by promoting more active root respiration. The root system must penetrate the soil. Often the soil offers certain difficulties; it may be too dense, too wet or too colloidal. In the latter case the root growth must necessarily be limited to a thin surface area where the roots will have access to air. A normal subaerial growth can only be obtained from normal subterranean growth.

Conclusions

1. Injury following molasses fertilization is due in most part to an increase in the iron and aluminum content of the soil solution as a result of the acid developed during the fermentation of molasses in poorly aerated soil. It would be the better policy to include coral rock or other forms of lime with molasses applications to heavy clay soils, and to plow the field soon after their application so as to obtain good aeration during the process of fermentation.

2. Nitrite nitrogen in the amounts which we have found present in the soil is not toxic toward cane growth.

3. Under field conditions in the soils which we have examined, there has been no evidence of denitrification except where aeration is poor On the contrary, there has been an active stimulation in nitrification beginning with the period immediately following the application of the molasses.

4. There was no influence upon the availability of phosphate in these soils during the period of the experiments.

5. Potash which is present in molasses is retained by the soil in a very available form.

6. It has been shown by experiments upon Kilauea Plantation soil that molasses reacts very much like a fallow in that it improves the mechanical condition of the soil, stimulates nitrification and root respiration and extends the foraging range of the roots.

Asphaltic Sealing of Reservoirs

A treatise on mainland processes and on a similar development for experimental procedure under Hawaiian conditions.

By F. E. Hance

Methods of reducing seepage in earth-bottom reservoirs have, to a certain extent, been under experiment on Hawaiian plantations for a number of years.

An economic, expedient and satisfactory sealing process has not, as yet, been fully developed.

Observations on reservoirs in some localities have shown that as fine silt, mud or other suspended matter settles from the still waters to the bottom of the basin (and builds up a "cake") the water retaining properties of that particular reservoir become correspondingly better.

On the other hand, a greater number of reservoirs are in use which apparently have not been improved after many years sedimentation has been deposited.

A few reservoirs on the islands of Maui and Hawaii have been serviced in natural basins which were left by extinct volcano craters.

Seepage from this crater type of reservoir is usually very excessive and, as a rule, the waste flow is rapid enough to carry off all residues of fines which would normally collect in an earth bottom basin.

We have numerous reservoirs on each of the Islands which have been built by damming a gulch. The dam may consist of an earth fill, with or without a stone facing, or it may be a plain hydraulic earth-fill structure. Where this type of reservoir has been built in fairly impervious soil and excessive seepage has developed, the trouble has most frequently been located either in the gravel floor of the basin, which was formerly an old stream bed, or it may appear in the artificial dam. This same type of reservoir has also been built on some of the Island plantations in very granular or porous soil. A few of these leaking basins which, obviously, have had to be abandoned and are now lying idle, are put in service only during an unusual emergency.

The problem of leaking reservoirs in the Hawaiian Islands is indeed a very general one and without any doubt a rather serious one.

The correction of seepage has been attempted in past years either by coating the reservoir with a layer of clay-like soil or by puddling the wet and empty basin with cattle driven repeatedly back and forth across the bottom.

In 1927, the department of chemistry at this Experiment Station, investigated the possibilities of a "chemical" or artificial puddling. The material from a number of reservoirs was sampled and experiments were made which showed that certain types of soil were rendered very impermeable by percolating a common salt solution through them. This operation involved a chemical base replacement in the soil colloid. A discussion of the chemistry of the salt treatment was made by

G. R Stewart and the writer in the *Hawaiian Planters' Record* for October, 1927. In these experiments we found that many of our soils, especially those from Hawaii, did not warrant a salt treatment because of their sandy character or because of a low concentration in colloidal constituents.

A few reservoirs on the island of Oahu were given a salt treatment. One of the smaller basins so treated gave encouraging indications of improvement but the nature of the treatment necessitated the impounding of fresh mountain water, instead of partially saline pump water. This was found necessary because of the likelihood of a reversal of the chemical puddling reactions occurring in the soil from the effect of the compounds in the saline water.

A brief explanation of the manner of securing salt puddling may clarify the above statement:

After a colloidal soil has been saturated with a salt treatment, it will still permit a salty solution to percolate through it at a restricted rate. If, therefore, a supply of fresh water is placed upon this "salted" soil, percolation will gradually be reduced and in some cases it may almost stop entirely. At this point the degree of puddling in the treated soil is at a maximum and the movement of pure water through it under a high hydrostatic head is, as a rule, very slow indeed. However, if a solution of common salt, or a solution of a combination of salts containing some calcium is applied above the treated soil it will gradually cause it to "open up." Water will begin to percolate at an accelerated rate and, in some cases, the original porosity of the soil will be restored.

A large part of our irrigation pump water contains appreciable amounts of common and calcium salts.

If the salt puddling scheme were entirely successful on all our soils (which is not the case) even then the salt treatment could only be utilized for basins designed to store fresh mountain water of very low calcium or sodium content.

As the investigation on puddling progressed it soon became apparent that our soils were so variable and the salt treatment even when applicable was subjected to such a stringent regulation on the character of water to be impounded, that a more practical scheme should be looked for if a satisfactory method of sealing was to be realized.

Early in 1928, the Oahu Sugar Company, Limited, began experimenting with a fuel oil application to the inner exposed surfaces of reservoirs which were badly leaking.

About the same time we began experimenting on small test depressions with a hot coating of Diesel oil containing dissolved petroleum asphalt. The results of the asphalt experimenting were quite satisfactory and later led to the asphaltic treatment at two large basins of the Waimanalo Sugar Company at Waimanalo, Oahu.

An investigation was begun and is now in progress on a characteristic property of asphalt which *may* render it not entirely satisfactory for sealing purposes. In long contact with clay or soil in fine division, under weathering conditions, asphalt becomes as brittle as chalk. This point was brought to the writer's attention by Joel B. Cox, engineer at the McBryde Sugar Company, Eleele, Kauai. Mr. Cox

suggested that the "chalking" of asphalt may prove a serious objection to its utilization for sealing earth reservoirs.

Conferring later with Mr. Stewart, chemist at this Station, a definite research was agreed upon to establish the cause and, if possible, the remedy for the asphalt deterioration. A search of the literature did not reveal a satisfactory explanation of the chalking phenomenon. Mr. Stewart then gave his endorsement to a plan whereby a research would be made to determine:

1. If colloidal adsorption of volatile and plastic constituents of the asphalt took place by contact with soil under alternately wet and dry conditions.

2. If the chalking was the result of the catalytic oxidation of the asphalt induced by contact with impalpably fine Hawaiian soil.

3. If the phenomenon was not but a simple weathering process due to evaporation and oxidation of the asphalt plastics by the sun, rain *and* contact with soil.

We had previously observed that the de erioration of asphalt was arrested in road beds in which crushed stone alone was brought in contact with the petroleum product.

We had also observed at dirt road intersections, and in road shoulder soil overlapping, that asphalt deterioration and road pitting were much more pronounced where the asphalt was in direct contact with the soil. The probable causes of deterioration as suggested in (1) and (2), above, are, we feel, subject to ready control.

A method of primary soil treatment, which is in use on mainland projects, apparently has reduced to a minimum any colloidal adsorption of plastic constituents and has also apparently removed conditions which favor the catalytic oxidation of the asphalt. This primary soil treatment will be discussed later. The matter of evaporation and deterioration by weathering of the asphaltic sealing compound is at present under observation at three locations on experimental installations on the island of Oahu.

In February, 1929, experimental work on asphaltic treatment of reservoirs in Hawaii was postponed while a study was made of mainland practices on similar undertakings. The present schedule of experiment has been modified and expanded as a result of the experiences gained in this investigational study.

The report which follows covers the investigation and carries also a description of the scheme which has since been adopted for experimental work in the Islands.

The Asphalt Association, New York City

Prevost Hubbard, director of the Association, discussed the problems of reservoir sealing with the writer. Mr. Hubbard stated that sealing problems were seldom encountered in the Eastern States. He advocated the continuation of our experimental program but added that he could not contribute any information as to the causes or remedy for asphalt chalking in Hawaii. He gave us several valuable suggestions on canal and ditch lining with asphaltic compounds. These will be discussed under that heading.

Mr. Hubbard offered to supply us with the literature which his Association is publishing and will continue to publish in the future. We are now receiving circulars and bulletins dealing with problems of grouting and sealing with asphalt and road maintenance problems with the same material.

F. E. Schmitt, Editor in Chief, Engineering News Record, N. Y.

Dr. Kirschbraun, Director Research, Flintkoto Co., E. Rutherford, N. J.

Dr. F. H. Rhodes, Professor, Industrial Chemistry, Cornell University, Ithaca, N. Y.

Dr. T. R. Briggs, Professor, Physical Chemistry, Cornell University, Ithaca, N. Y.

The above group of industrial scientists were consulted individually for the purpose of obtaining more detailed information on the composition, manufacture and cost of preparing in Hawaii the water-soluble asphaltic emulsion which has recently become popular on some of our plantations.

This asphaltic emulsion appears on the market in consistency about as heavy as a very thick paint. For use it is diluted with water until a free flowing liquid is obtained. Unlike oil paints, this preparation may be applied to wet wood or metals without the applied coat later peeling from the painted surface. Leaking wood flumes, for instance, may be repaired and painted without the necessity of first drying out the lumber before making the application. The asphaltic emulsion will adhere to and make a very good job of covering on an old water-soaked plank.

After the applied coat has become dry (5 or 6 hours), water thereafter has no more effect on it than it has on any other painted surface which has become dry. For flume work and timber treatment, calling for additions of water or oil soluble toxic chemicals to combat termites and other insects, this type of paint is ideal.

We learned that the compound is made by a patented process. Tar acid and cresolic fractions from by-product coke oven residues are added to naphtha solutions of petroleum asphaltic oils. Partial saponification of the tar acids in the mixture is secured by additions of strong soap (or alkali) and injection of live steam. The mixture then is ready for dilution with water, the product remaining indefinitely in a condition of perfect emulsification.

The preparation of the compound in the Islands would involve some experimentation and perhaps a little difficulty with the patent rights of the manufacturers. Its use has not become extensive enough to warrant any further investigation at this time, although we have the necessary information to begin the experimenting with its preparation.

In May, 1929, the compound could be purchased for 16 cents a gallon in 20-ton lots, f. o. b. New York City, unreturnable steel drums extra.

Asphalt Grouting for Plugging Subterranean Tubes and Fissures in Reservoirs and Dams

We learned from C. A. Bock, vice-president, Morgan Engineering Company, Dayton, Ohio, that hot asphalt grouting had been successfully employed for clos-

ing large underground tubular leaks (lava tubes) in reservoirs situated in former volcanic regions.

We are corresponding with an engineer in Chicago, L. F. Harza, who has had charge of several large undertakings in this type of reservoir sealing.

The scheme has been employed with success against a stiff movement of water through the tubes to be plugged. A simple electric resistance device is used as a part of the delivery equipment which carries the hot asphalt to the channel which it is desired to close.

On one of the Hawaiian plantations a very large reservoir, it appears, has been leaking excessively through underground channels. The district is one where lava tubes may possibly be found.

During the construction of the dam for this reservoir two sump holes developed which carried down a part of the unconsolidated fill. In a short time the downward sinking of earth ceased but the movement may likely be indicative of subterranean tubes or channels. At the present time during periods of low water in the basin, extended longitudinal fissures may be seen in the dam at about the twenty-foot level. The openings in the fissures are, in places, as wide as a man's body. The fissures may or may not be connected with any underground channels. The leakage in this reservoir has been estimated at between ten to twenty million gallons per day. No trace of the leak has ever been found as appearing at the surface of the slopes below the dam.

Considering the history of this structure, a systematic determination of seepage per day at various water levels and a careful and frequent examination of the dam and reservoir may result in the location of the larger leakage channels which apparently are contributing to the existing seepage. Plugging with asphalt or cement might then be accomplished.

We are prepared to furnish information on the manner of applying an asphalt grouting to subterranean channels, should it be desired.

Seepage when found in mainland reservoirs, of earth-bottom and side-wall construction, is usually traced to the dam which impounds the water.

The use of asphaltic compounds as a seal against seepage, at areas in the reservoir other than the dam, is made secondary to the preservative effect that asphaltic oils have upon the water, the inhibiting effect the materials have upon bacteria and to the value of asphalt in weed control from the rim of the basin to the low water level on the banks.

Since most of the mainland catchment projects are designed to impound water for municipal uses, the contamination from fungous growths is sometimes controlled by periodic asphaltic oil treatment on the entire inner and upper basin. Asphalt is said to "sweeten" the water and to inhibit fungus growth.

Weed control is maintained on the slopes and banks of reservoirs by spraying with water emulsion of asphalt oil compounds. The wide use for which heavy asphalt is utilized may, however, be seen in the rip-rapping and sealing against

seepage on earth dams at the very large projects in southern California. The asphalt coating protects the soil in the dam from erosion due to rippling and wave motion and it seals the basin at the point where seepage most usually develops. For the purpose only of sealing against seepage on artificial dams asphalt has been used in California with unquestionable success. In this respect the mainland problems of water storage approximate the conditions we have in the Islands, not only on our dams, but due to our more or less open soils, by preference, on many of our entire basins. A careful study was therefore made of the methods in use by southern California cities in this work.

The reason that a comparatively localized area was selected for a more specific study of asphaltic reservoir treatment was due solely to the fact that the development of the various processes of technic in use there far exceeded the methods of any other known group of cities or of municipal engineers.

The methods employed will be described below and photographs will be shown which illustrate the procedure.

In the early part of this discussion we took up the question of "granulation" of asphalt by its contact with soil. Irrespective of the causes of this deterioration of the asphalt the process is delayed by the California primary reservoir soil treatment which is designed to kill weed and grass seeds. The deterioration process is further delayed after completion of the asphalt sealing operations by an oil spraying at yearly intervals on the banks of the reservoir above low water. The spraying is designed to circumvent the encroachment of weeds and seeds from outside sources.

Before the application of the heavy asphalt oils in a sealing treatment, the moistened soil on the inner surface of the reservoir or dam (or both) is sprayed with a low grade "Diesel" or fuel oil in an amount sufficient to cause a penetration of about 3 inches below the soil surface. One gallon of oil per square yard of surface constitutes a single application. Two applications may be required to secure the 3-inch penetration.

Following the first and successive oil applications the surface of the reservoir is harrowed with a Killifer scarifier. This operation is made in order to bring all plant seeds in contact with the oil, and also to insure and to secure thorough incorporation of oil and soil for the under asphalt foundation.

This primary oil application serves another purpose, we think. It undoubtedly has the effect of retarding the granulation of asphalt which later is placed upon it. We examined treated reservoirs, one 5 years and two 6 years after treatment, which still exhibited a pliable and solid asphaltic coating.

It appears logical to assume then that the primary oil treatment breaks up the soil colloidal influences which tend to granulate the asphalt. Heavy asphaltic treatment is next applied on the scarified soil.

An application of oil containing 40 to 50 per cent asphalt is sprayed on (at 250° F.) at the rate of one gallon per square yard of soil surface.

The soil is again scarified and a final coating of oil containing 90 per cent asphalt is flowed on, one gallon per square yard, at a temperature of 400° F. After the final oil coating a layer of stone screenings, free from dust and passing

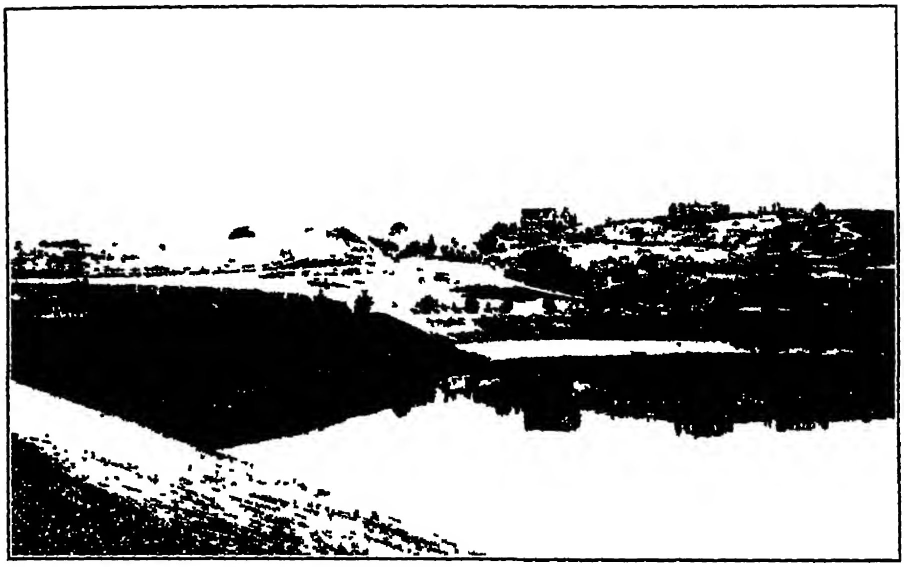

Fig. 1. Oiled reservoir, City of Los Angeles.

Fig. 2. Asphalt treatment. Reservoir, City of Los Angeles. General view. Bank on left has had final application.

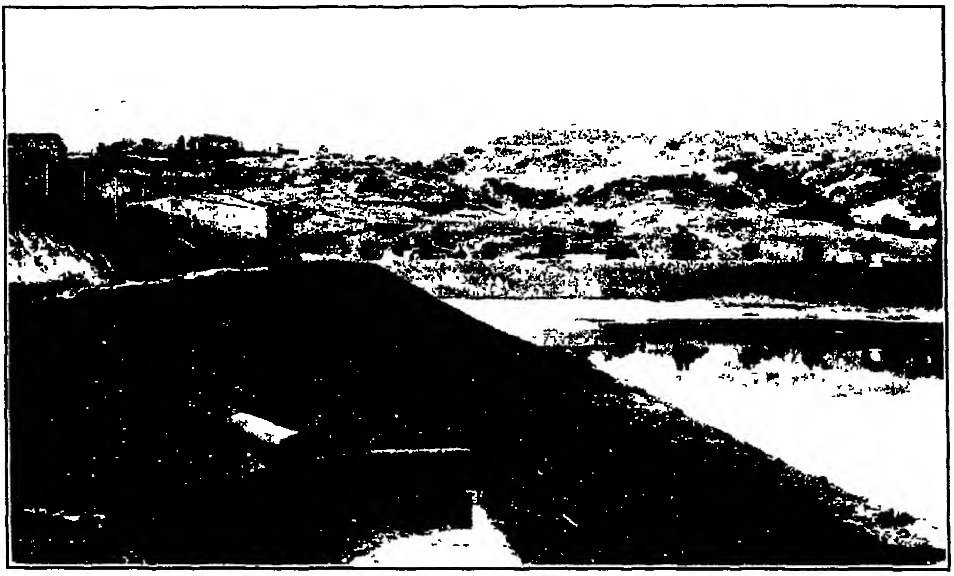

Fig. 3. Asphalt and oil treatment. Reservoir, City of Los Angeles. After application of "70 per cent" oil.

Fig. 4. Asphalt and oil treatment. Reservoir, City of Los Angeles. Appearance of surface after final application of L3 (90-95 per cent) asphaltic oil.

Fig. 5. Asphalt treatment. First step in preparation of surface. Scarified to 3-inch depth by cultivator. Followed by application of 60 per cent asphaltic oil—one gallon per square yard.

Fig. 6. Asphalt treatment. After an application of 60 per cent oil, the surface is scarified and 70 per cent asphaltic oil is applied—one gallon per square yard. The surface is then rolled. (Roller shown in operation.) After rolling, L3 (90-95 per cent) asphaltic oil is applied as a finishing coat.

a ¼-inch screen, is applied at the rate of 2 pounds per square foot of surface. The entire treated area is then rolled with a roller having a weight of 500 pounds per lineal foot of bearing surface.

A finishing coating of the 90 per cent (asphalt) oil is usually applied as a surface dressing. In the Los Angeles District the final surfacing coat is left to the option of the city engineer. It is, however, generally applied. Figs. 1, 2, 3, 4, 5 and 6, with descriptive captions, illustrate the asphaltic sealing operations in California. These prints were supplied through the courtesy of Norman H. Angell, at the San Francisco office of the Standard Oil Company of California.

Mr. Angell kindly made an appointment for the writer by wire with J. F. Jeffries, manager of the Los Angeles office of his company. Mr. Jeffries made arrangements with Messrs. Oliver Lamson, A. C. Craig and B. F. Dupuy for the writer's inspection of several reservoirs in the Los Angeles District as the guest of the Standard Oil Company of California.

Details of asphalt treatment were observed at various stages during the process. Completed jobs were inspected which had been in service up to six years without any subsequent applications of heavy asphaltic oils.

In company with Messrs. A. C. Craig and B. F. Dupuy the following reservoirs were examined for the special features which appear in the brief notes included in the description of each project visited:

Pressure Break Reservoir, Beverly Hills:

Treated by "cultivating" into the soil of the reservoir a 40 per cent asphalt oil at 2 gallons per square yard of surface. After rolling the treatment an additional coating of 90 per cent asphalt oil was applied and rolled. The final applications of heavy oil were about to be applied in June, 1929.

Stone Canyon Reservoir, Above Beverly Hills:

Built with hydraulic-fill dam. Up-stream face of dam covered with solid asphalt. Banks of reservoir were treated by the standard method of asphalt application as described in this paper. Apparently a very effective seal was secured.

Encino Reservoir, Los Angeles:

This reservoir was visited during the period that a supplementary oil application was being applied. The control of weed encroachment and the freshening of the previously applied asphalt coating on the dam and banks were the objectives of the supplementary application. In order to secure a better penetration of oil to the inner fibre of the weeds an aqueous emulsion of two parts water and one part fuel oil was used. The mixture was delivered to the pump which operates the spraying device from a power boat maintained at this reservoir. To prepare the simple emulsion the oil and water were simultaneously delivered from a two-compartment tank to a centrifugal pump in the bow of the boat. An operator on the reservoir bank directed the emulsion discharge from a hose line which was attached to the pump.

Weeds were destroyed by a single application of the emulsion. The asphalt-treated bank was softened and renewed at the same time.

The oil employed in this class of treatment was a thin fuel oil containing about 30 per cent asphalt. The treatment on this basin was made by the standard practice as described under Lippincott specifications.

Lower San Fernando Reservoir, San Fernando, California:

This reservoir has a capacity of 18,000 acre feet of water. It is closed by an hydraulic-fill dam which has remained intact through several severe quakes.

The lower inner face of the dam is paved with concrete blocks. The upper surface has lately been rip-rapped with asphalt to save an undermining of the paving which threatened to become serious. The reservoir proper has received the standard Lippincott asphalt treatment. The banks above low water have received the yearly emulsion treatment which was described under the Encino Project. No trace of weeds or grass was found on any of the treated surfaces. A thick and unbroken coating of flexible asphalt persisted on the dam facing despite the fact that five years had elapsed since the treatment had been applied. An opportunity was found to examine the outside (downstream) facing of the dam at elevations considerably below the water level in the lake.

No seepage was found anywhere in the valley below the dam. Even at points below the floor of the reservoir the dam was dry and powdery and did not support vegetation.

Kenneth Q. Volk, of the firm of J. B. Lippincott, Los Angeles, very kindly supplied us with their specifications for treating reservoirs. A copy of the specifications appears below:

The oil used for asphalt treatment shall be "Gilmore Road Oil" or an oil of equal quality. It shall be applied at a pressure of at least 30 pounds per square inch by a pressure spraying machine which will spread the oil uniformly over the surface. Three applications of oil shall be made and not less than one gallon of oil per square yard of surface shall be used for each application. After each application the surface shall be scarified with a Killifer scarifier so as to secure the maximum penetration. A minimum penetration of 3 inches will be required. For the first application oil containing from 40 to 50 per cent asphalt shall be used. For the second application oil containing from 50 to 60 per cent asphalt shall be applied, at a temperature of not less than 250° F. For the third application oil containing not less than 60 per cent or more than 90 per cent asphalt (the percentage used being subject to the approval of the engineer) shall be applied at a temperature of not less than 400° F.

Before each application of oil the surface of the dam shall be thoroughly sprinkled with water and the oil sprayed on while the ground is still wet. After the final application of oil, a layer of stone screenings which will pass a ¼-inch screen and free from dust shall be spread in sufficient quantity to secure not less than two pounds of screenings per square foot of surface. The whole face of the dam shall then be rolled with a roller having a weight of not less than 500 pounds per lineal foot of bearing surface.

Mastic Ditch Lining

Information on "flexible" ditch coatings with asphaltic bases was difficult to secure from the engineers in charge of the mainland operations which were visited.

The staff of the McGraw-Hill Company and Mr. Hubbard, of the Asphalt Association, both in New York City, gave us information on this topic, however, which we plan to use as a basis of experiment.

The water soluble asphaltic emulsions or low-grade solutions of asphalt in fuel oil are worked into a stiff paste with Portland cement or powdered lime rock.

(The term "plastic cement" as applied to this type of coating was probably given to the mixture because Portland cement was used on the mainland in its preparation. The cement, however, does not function in these mixtures as it does in concrete. It is employed simply as a dispersing medium to check the fluidity of oil or asphaltic base and to act as a filler in the mixture. As a substitute for Portland cement, powdered gypsum or lime rock have been used with equal success.)

The prepared paste is applied by hand to the ditch surface in a layer about 1½ inches thick. In a few days it solidifies into a solid coating of horn-like surface consistency. Rapidly moving water will not tear it from its position, it is claimed.

We propose to carry out experiments in Hawaii in preparing and laying a plastic ditch lining. As a substitute for Portland cement we shall probably attempt to employ a finely powdered coral rock. George Chalmers, Jr., manager of the Waimanalo Sugar Company, has suggested that a very fine sand, which is available on his plantation, may also be used in the ditch lining as a substitute for cement.

The general details of the experimental program on canal and ditch lining have been formulated chiefly on the specifications secured from the Standard Oil Company of California. A copy of the specifications follows:

SPECIFICATION FOR ASPHALTIC CANAL LINING (MASTIC DITCH LINING)

General

Sec. 1. (a) **General Description of Specifications.** This specification covers the construction of an asphaltic canal lining and applies only when the materials used meet the requirements of the standards specified. It is the intent and purpose of this specification to cover specifically the standards of materials to be used and the arrangement thereof in such a manner as to furnish a dense and compacted asphaltic canal lining and to a compacted thickness of one and one-half (1½") inches. This specification does not comprehend the preparation of the subgrade, terms under which this specification is executed, nor anything extraneous to the actual preparation and construction of the asphaltic canal lining.

(b) **Composition of Mixture.** The asphaltic mixture shall consist of approximately 76 per cent sand and approximately 10 per cent mineral filler uniformly mixed and with approximately 14 per cent asphalt and laid to a compacted thickness of one and one-half (1½") inches upon the previously prepared bottom and side slopes of the canal which shall previously be sprinkled with one-half (½) gallon per square yard of two (2) per cent Cresoil. (Cresoil may be obtained through Howard and Beal, 112 Market Street, San Francisco.)

Materials

Sec. 2. **Sand.** (a) The sand for the asphaltic mixture shall consist of hard, uncoated, sharp, durable grains, free from clay, loam or other foreign material.

(b) When tested by means of laboratory screens, the sand shall consist of one or more commercial products and shall pass the openings of a sieve having 10 meshes to the linear inch.

Sec. 3. **Mineral Filler.** The mineral filler shall consist of thoroughly dry limestone dust or Portland cement, free from clay, loam or other foreign materials, and when tested by means of laboratory sieves shall meet the following requirements:

Passing 30 mesh sieve—100 per cent
Passing 200 mesh sieve—not less than 65 per cent

Sec. 4. **Asphalt.** The asphalt used under these specifications shall be Calol Asphalt "D" Grade. It shall be homogeneous, free from water; shall not foam when heated to 175° C. (347° F.). It shall meet the following requirements for physical and chemical properties:

1. **Purity.** It shall be not less than ninety-nine (99) per cent soluble in cold carbon disulphide (CS_2).

2. **Penetration.** The penetration at twenty-five (25) degrees Centigrade (77° F.) 100 g. 5 sec. shall be between the limits of four (4) millimeters and six (6) millimeters.

3. **Ductility.** The ductility at twenty-five (25) degrees Centigrade (77° F.) shall be not less than 100.

4. **Volatility.** The loss on heating at one hundred sixty-three (163) degrees Centigrade (325° F.) for five hours, shall not be more than one per cent Penetration for the residue of twenty-five (25) degrees Centigrade (77° F.) 100 g. 5 sec. shall not be less than fifty (50) per cent of the original penetration.

5. **Flash Point.** The flash point shall not be less than one hundred seventy-five (175) degrees Centigrade (347° F.).

6. **Solubility.** The solubility in cold carbon tetrachloride (CCl_4) shall not be less than ninety-nine (99) per cent.

Sec. 5. **Methods of Testing.** Methods of testing shall be as follows:

(a) **Sand:**

1. Sieve test for sand, Standard Method D7-18, American Society for Testing Materials.

(b) **Mineral Filler:**

2. Sieve test for mineral filler, Standard Method D7-18, American Society for Testing Materials.

(a) **Asphalt:**

1. Solubility in carbon disulphide (CS2) Standard Test, DF-11, American Society for Testing Materials.

2. Penetration, Standard Test D5-16, American Society for Testing Materials.

3. Ductility, Tentative Test D113-21T, American Society for Testing Materials.

4. Volatilization Test. Standard Test D6-20, American Society for Testing Materials.

5. Flash Point (Open Cup). U. S. Dept. of Agriculture, Bulletin 314, page 17.

6. Solubility in carbon tetrachloride (CCl4) U. S. Dept. of Agriculture Bulletin 314, page 30.

PREPARATION AND COMPOSITION OF MIXTURE

Sec. 6. **Preparation of Asphalt.** The asphalt shall be heated in kettles or tanks designed to secure uniform heating of the entire contents, and shall be brought to a temperature of 200° F. to 300° F.

Sec. 7. **Preparation of Sand and Mineral Filler.** (a) The sand for the asphaltic mixture shall be thoroughly dried and heated to a temperature of 300 to 350° F. When a

mixture of two or more sands is required in order to produce a material conforming to the requirements of Sec. 8, such combination shall be made either before the sand is fed into the drier or by simultaneously feeding the individual sands into the drier in proper proportions.

(b) The mineral filler for the asphaltic mixture shall be stored separately and shall not be heated with the sand but shall be thoroughly mixed with the sand for from ten (10) to fifteen (15) seconds before the asphalt is added.

Sec. 8. **Preparation and Composition of Asphaltic Mixture.** (a) The sand for the asphaltic mixture shall be measured separately for each batch. The mineral filler shall be added from sacks of definitely known weight. The sand and mineral filler shall be mixed in accordance with the quantities and sizes shown in Sec. 8 (b). The required quantity of hot asphalt for each batch shall be measured by actual weighing with scales attached to the asphalt bucket. The mixture shall be made in an approved mixer by first charging with the sand and the mineral filler, and then adding the asphalt. It is the intent of this specification to provide for thoroughly mixing the sand and mineral filler with asphalt. Such a mixture can be secured in an approved mixer in approximately one (1) minute. Where a homogeneous mixture in which all particles of sand and filler are uniformly coated is obtained in less than one (1) minute, the time of mixing may be varied at the direction of the engineer.

(b) The constituents of the asphaltic mixture shall be combined in such proportions as to produce a mixture conforming to the following composition limits by weight:

Passing a sieve having 10 meshes to the linear inch, retained on a sieve having 10 meshes to the linear inch	20 to 40 per cent
Passing a sieve having 40 meshes to the linear inch, retained on a sieve having 80 meshes to the linear inch	35 to 50 per cent
Passing a sieve having 80 inches to the linear inch, retained on a sieve having 200 meshes to the linear inch	15 to 25 per cent
Passing the 200 mesh sieve	10 to 15 per cent
Asphalt	13 to 15 per cent

The proportions shall be varied within the limits designated as directed by the engineer.

Sec. 9. **Paving Plant Inspection.** The engineer or his authorized representatives shall have access at any time to all parts of the plant for the verification of weights or proportions and character of materials, and determination of temperatures used in the preparation of the mixture.

Sec. 10. **Transportation of Mixture.** The asphaltic mixture shall be transported from the plant to the work in tight conveyances previously cleaned of all foreign materials, and when directed by the engineer, each load shall be covered with canvas or other suitable material of sufficient size to protect it from weather conditions. In case oil is used to prevent the adhesion of the mixture to the bed of the conveyance, an excess of oil shall not be permitted. No loads shall be sent out so late in the day as to interfere with spreading and compacting the mixture during the daylight unless artificial light satisfactory to the engineer is provided.

CONSTRUCTION

Sec. 11. **Cresoil Application.** A two per cent solution of cresoil shall be applied at the rate of one-half (½) gallon per square yard upon the previously prepared bottom and side slopes of the canal. Sufficient time shall be allowed for the penetration of the cresoil before the application of the asphaltic mixture.

Sec. 12. **Placing Asphaltic Mixture.** Prior to the arrival of the asphaltic mixture on the work the prepared base and sides shall be cleaned of all loose and foreign materials. The mixture shall be delivered at temperature of 275 to 325° F. Upon arrival on the work it shall be at once uniformly spread by means of shovels, forks, or mechanical spreaders in a loose layer and raked to correct depth over the area designated by the engineer. No mixture shall be spread when the base is wet or when weather conditions are unsuitable.

Sec. 13. **Compacting Mixture.** (a) While still hot the asphaltic mixture shall be thoroughly and uniformly compressed with hand roller as approved by the engineer. In rolling the side slopes the rollers shall be drawn up the slope over the loose asphaltic mixture, and no rolling down the slope shall be permitted until the roller has made at least one trip up the slope over the loose asphaltic mixture. Rolling shall continue at right angles to the center line of the canal overlapping on successive trips by at least one-half the width of the roller, until suitable compaction is obtained. The motion of the roller shall at all times be slow enough to avoid displacement of the hot mixture, and any displacement occurring as the result of the reversing of the direction of the roller, or from any other cause, shall at once be corrected by the use of rakes and of fresh mixture when required. The wheels of the roller shall be properly moistened to prevent adhesion of the surface of the mixture to the roller, but an excess of water or other materials for this use shall not be permitted.

(b) Along headers, joints, structures, and places not accessible to the roller, the asphaltic mixture shall be thoroughly compacted with hot tampers to produce sealed joints.

(c) The surface of the mixture after compression shall be true to the established grade. Any mixture which during construction becomes loose or broken and mixed with dirt or in any way defective shall be immediately remedied by removing the asphaltic mixture at such spots and by replacing it with hot fresh asphaltic mixture, which shall be immediately compacted to conform with the surrounding area.

Sec. 14. **Joints in Surface Course.** The placing of the asphaltic mixture shall be as nearly continuous as possible, and the roller shall pass over the unprotected end of the freshly laid mixture only when the laying is to be discontinued for such a length of time as to permit the mixture to become chilled. In such cases provision shall be made for proper bond with new asphaltic mixture by cutting or trimming back the joint while the material is still hot, so as to expose an unsealed or granular surface for the full specified depth of the mixture. At the end of each day's work, joint shall be formed by laying and rolling against boards of the thickness of the compacted mixture, or by such other methods as may be approved by the engineer. When the laying of the asphaltic lining is resumed, the exposed edge of the u joint shall be painted with a thin coat of hot asphalt and fresh mixture shall be raked against the joint, thoroughly tamped with hot tampers and rolled. Hot smoothing irons may be used for sealing joints, but in such cases extreme care should be exercised to avoid overheating the surface. In cases where joints are made between the asphaltic mixture and other structures or linings, the exposed edge of these structures or linings shall be painted as specified above.

Sec. 15. **Protection of Lining.** Where the transverse edge of the asphaltic lining does not terminate against other structures or linings, this edge shall be curved and buried to a depth of one foot below the surface of the lining. Sections of newly compacted asphaltic lining shall be protected for at least six hours, or until the asphaltic mixture has become properly hardened by cooling.

Gumming Disease of Sugar Cane

By J. P. Martin

Under the guidance of D. S. North, pathologist, Colonial Sugar Refining Company, Ltd., Sydney, and A. F. Bell, pathologist, Bureau of Sugar Experiment Stations, Department of Agriculture, Brisbane, the writer had an opportunity, during 1929, to study the diseases of sugar cane occurring in Australia. It was possible to observe the major cane diseases such as gumming, leaf scald, Fiji disease, and downy mildew under field conditions and also to become familiar with their diagnostic symptoms. Many of the minor cane diseases also were noted and studied in the fields visited both in Queensland and in New South Wales.

Gumming disease is considered one of the oldest diseases affecting sugar cane and has often been a subject for discussion in the literature. The object of this paper is to discuss gumming disease in detail presenting the geographic distribution and history of the disease, the diagnostic symptoms used in recognizing the disease and the measures now employed for its control.

Gumming disease was much more severe in New South Wales than in Queensland; in fact, all studies conducted on the disease were carried out in New South Wales in association with Mr. North, to whom we are indebted for our recent knowledge on the transmission of the disease. To mention a specific example of the seriousness of gumming, Mr. North pointed out that the disease started in the cane fields in the Richmond River district about 1919. During the next four or five years severe crop losses resulted and it was quickly learned that such desirable commercial varieties as Badila, Mahona and M 1900 could not be cultivated profitably because of their susceptibility to the disease. These susceptible varieties were replaced with inferior commercial varieties, such as Malabar (Yellow Caledonia) and H. Q. 5. The disease has been greatly reduced through the substitution of resistant varieties. A loss in sugar per acre followed the substitution, and North (16) has stated, "Every individual grower is contributing a large portion of his income annually in the shape of diminished crop returns from the inferior but resistant varieties." The cane growers in New South Wales are permitted to plant only approved canes, a list of which is published at intervals by the Colonial Sugar Refining Company, Ltd. This list includes those commercial varieties that are resistant to specific diseases in the different districts. A cane variety may be planted in one locality but not in another simply because gumming may not be a problem in one district, while it is a serious problem in another. This rigid system is largely responsible for the present control of cane diseases in New South Wales and the growers fully appreciate the merits of the system.

Prior to 1912, gumming disease was a serious menace in Fiji, according to Mr. North, but with the adoption of certain definite control measures the disease has rarely been observed since that time even though susceptible varieties are still being grown.

Geographic Distribution and History

According to the literature gumming disease now occurs in the following sugar cane countries: Brazil, Mauritius, Australia, Fiji, St. Kitts, Porto Rico, St. Lucia, Colombia and Guadeloupe. It has also been reported as occurring in Java, Borneo, New Guinea and Argentina by the late Erwin F. Smith but confirming evidence regarding its presence in these countries is lacking.

In Java, and probably Borneo, the disease once thought to be gumming has been definitely shown by Wilbrink (20) to be leaf scald disease. Leaf scald disease is known in Java as "Gomziekte" and for many years there existed a great deal of confusion regarding the identity of leaf scald or gomziekte and the Australian gumming disease. Both North (13) and Wilbrink (20) have shown that these diseases are distinct. The present status is that the Java gumming disease as described by Wilbrink is identical to that of leaf scald disease which has been described independently by North (13) in Australia. Australian gumming disease is not known to exist in Java.

Many varieties of *Saccharum officinarum* are affected with the disease. Two varieties of *S. sinense* have proved susceptible to artificial inoculations. The earliest record indicates that the disease originated in South America, but since sugar cane is not indigenous to that country, it is maintained by some investigators that the original host may have been one of the large grasses of South America

Gumming disease has been reported under the following names: Cobb's disease of sugar cane, Gummosis, Gomosis, maladie de la gomme, and gum disease. The first authentic record of the disease was by Dranert, in 1869, whose observations were made in the sugar region of the province of Bahia, Brazil. Dranert (9) stated that the disease had been epidemic for the preceding six years and that it had been recognized as a distinct disease for a much longer period. The disease was finally controlled by replacing the variety Otaheite with Cavengirie which is not immune but is highly resistant. Dranert (9) was the first investigator to find and associate bacteria as the causal agent of the disease. He observed bacteria in the gum or exudate and considered these organisms to be the cause of the disease. The following is a translation by Erwin F. Smith (18) of a portion of Dranert's work:

> On the contrary, as an infallible sign of the disease there appears in the first place a red stain in the wood and the surrounding cambium tissue of the nodes. As the disease progresses this stain spreads in the same bundles through the whole shaft of the cane, while the parenchyma for a time retains its natural clearness. In the fully developed disease a yellow, thick fluid substance flows out of the bundles. This substance hardens in the air, but dissolves in water, and under the microscope, with very high magnifications, is seen to have only a granular structure. When dissolved in water one can make out very minute cells lying in amorphous heaps, or attached to each other in necklace fashion.

There is no question but that the Brazilian disease studied by Dranert was the same disease subsequently described in Australia by Cobb (7).

Cobb (6) observed the disease in 1893, in the Clarence River district and also in the Richmond River district in New South Wales. According to his observations at that time gumming was very prevalent and serious crop losses occurred.

Cobb was able to trace the first appearance of the disease to 1876 in the Lower Clarence River district; and he also reported the occurrence of the disease in Queensland, 1893. In 1895, Tryon (19) talked with a number of persons who recalled having seen the malady two years earlier, one of whom having seen it as early as 1884, in a cane variety known as Rappoe in Queensland.

The first authentic detailed description of the disease and the identification of the causal organism was by Cobb (6). He named the disease "gumming of sugar cane" and the organism *Bacterium vascularum.* He did not use pure cultures in reproducing the disease but his inoculations were direct, that is, healthy canes were inoculated with the fresh gum taken from the ends of freshly cut vascular bundles under aseptic conditions. Cobb's studies on this disease have served as a basis for subsequent descriptions and his conclusions regarding the aetiology of the disease were later confirmed by Greig-Smith (10) and Erwin F. Smith (17). Cobb failed to observe and describe the streaks on the leaves as a symptom of the disease.

Boname (4), in 1894, reported Cobb's gumming disease as common in Mauritius on a variety called La Canne Bambou (Bamboo cane), and considered it to be their most serious local cane disease. A correspondent of *Sugar Cane* (1) in 1894, at Pernambuco, Brazil, described a serious disease of cane and from his descriptions it appears that the unknown disease was undoubtedly gumming. He described the formation of gum, the discolored vascular bundles, the early drying of the leaf tips followed by the premature death of the cane; the canes which did not die failed to yield ratoons and the juice of diseased canes was extremely difficult to crystallize. The nature of this disease was not explained and the varieties attacked had been under cultivation for many years. The two varieties, Otaheite and Creole were highly susceptible and the correspondent advanced the theory that these varieties were "running out." Others were of the opinion that the condition was due to depleted soil, but these varieties even failed on rich virgin soil. Since no cure of the disease could be found these two varieties were discarded, and replaced with introduced varieties of foreign origin. The new canes were not attacked and this particular case is one instance where an unknown disease was controlled by substituting what proved to be resistant varieties for the susceptible ones without knowing the nature of the trouble.

Greig-Smith (10), in 1902, published a paper in Australia on "Gummosis" of sugar cane. He isolated the pathogen and described its growth on various culture media. From his studies he concluded that the gum in diseased canes was of bacterial origin and not a secretion of the host plant. The gum produced on the surface of cane-gelatin or agar media was identical with that found on freshly cut surfaces of affected stalks.

In 1904, Smith (17) published the results of his carefully planned experiments with gumming disease. He used pure cultures for his inoculation studies which were conducted in the greenhouse at Washington, D. C. He stated that he had never seen the disease in the field. His conclusions verified the fact that *Bacterium vascularum* (Cobb) Greig-Smith, was the causal organism and fully confirmed the results of the work of previous investigators.

Cobb's (8) third report, which appeared in 1905, on gumming of sugar cane

merely restates the findings of Smith, Greig-Smith and his own determinations in relation to the disease.

In 1914, Smith (18) fully reviewed the early literature on the subject and described his previous investigations, these having been carried out much further since 1904. Most of our exact knowledge of the disease is due to the outstanding work of Smith.

As stated above the disease was first reported in Brazil, then in Mauritius and later in Australia. From studying the early records regarding the spread of the disease it is quite evident that the disease was carried from country to country in cane cuttings. In 1869, a shipment of cuttings was sent from Brazil to Mauritius and in all probability some of these cuttings were taken from cane districts where gumming disease existed since the disease appeared in Mauritius the following year. The disease made its way from Australia to Fiji through cuttings due to the free interchange of canes at that time. This information merely points out the ease with which the disease may be spread through the importation of foreign canes.

The disease was identified by Matz (11) in Porto Rico, February, 1920. He pointed out that the disease may have existed to a limited extent the previous year.

Ashby (2) reported that the disease was first noted in 1925 in St. Kitts and St. Lucia, British West Indies.

Chardon and Toro (5) found the disease present in Colombia in 1926 and they considered it to have been prevalent there for many years. It had probably been introduced from Brazil, where it was a serious malady as early as 1869.

Williams (21) reported that a survey made March, 1929, showed that the cane variety Ba. 11569 on plantations in Guadeloupe was generally affected with gumming disease and that this was the first record of its occurrence in the island.

Description

Smith (18) presents a concise description of gumming disease, as follows:

> The most conspicuous signs of this disease are dwarfing, striping of the leaves, dying of the tops, decay of the heart (terminal bud), and the appearance of a yellow slime or gum in the bundles of the stem and leaves. Many of the bundles are also stained red. Microscopic examination shows that this gum contains millions of bacteria. Cobb and Boname agree that there is also a reduction of the sugar content.
>
> The disease is primarily one of the vascular system but in advanced stages the parenchyma is attacked, especially the soft tissues just below the terminal bud, and cavities are formed which are filled with the yellow bacterial slime. Sometimes these cavities contain as much as a teaspoonful of the slime. In the later stages of the disease, the interior of the leaf sheaths is rusty brown and covered with the sticky bacterial slime, which is also sometimes seen oozing from other portions of the leaf. This slime oozes from the stomata.

The appearance of the leaf streaks is the most useful symptom in detecting the earliest stages of the disease in the field. These symptoms are readily recognized on the young plants affected with the disease. The disease is confined to the older leaves and the symptoms seldom occur on the five youngest leaves. The streaks

are yellowish in color, often containing reddish-brown spots or blotches, varying from 1/8 to 3/16 inch in width, while their lengths vary with their age and development. The streaks are frequently one-half the length of the leaf. The streaks may develop any place on the leaf depending upon where the primary infection takes place, traveling both upwards and downwards in a well-defined line following the course of the vascular bundles. The affected tissue in the older streaks becomes brown or ashy in color and 1/8 to 1/2 inch wide. The streaks taper off at each end and become a yellow or yellowish brown color. Occasionally the streaks appear on the upper half of the cane leaf and run out at the leaf tips or margins. Such streaks are more pronounced on leaves of susceptible canes following periods of wet weather but may disappear almost entirely during periods of dry weather. Several streaks may develop on the same leaf and in badly affected fields the cane has a dried appearance due to the amount of dead tissue at the tips of the leaves.

Fig. 1. Exudation of gum on freshly cut surface of diseased stalk. Broadwater, N. S. W. (Photo by J. P. Martin.)

Gumming disease when confined to the leaves does not cause the losses which occur when the disease travels down the leaf blade, through the leaf sheath and into the growing stem; this condition is known as the systemic form of the disease. Stalk infection or systemic development varies with the variety and the growing conditions of the cane. In case the leaf symptoms disappear no external signs are present and the stalk may harbor the disease for 12 to 18 months. In such cases a cane may appear healthy, although it is diseased and plants grown from cuttings from such stalks may develop the disease.

The systemic form may slightly depress the growth of the young cane while in old stalks the stunting of the growth is much more severe, the leaves become narrow, and the stalk in time becomes noticeably shortened or tapered toward the growing point. Following systemic infection the tops may die and a top rot may result.

The outstanding diagnostic symptom of systemic gumming disease is the exudation of a yellowish to orange-red slime that quickly forms on the surface of freshly cut ends of affected stalks as shown in Fig. 1. Excellent colored plates showing gum exuding on cut ends of affected stalks were published by Cobb (8) in 1905. Another excellent colored plate showing the presence of the streaks on the leaves, lysigenous cavities in the stalk and the beads of gum exuding on the cut ends of an affected stalk appears in a publication by Bell (3) in 1929. With stalks slightly affected the test for gumming is made by immediately placing fresh cuttings in a vasculum, or closed container, thus subjecting it to a high humidity for 30 to 60 minutes. At the end of this period small beads of gum may be observed on the cut ends. Gum frequently may be obtained from affected leaves by subjecting them to the "sweating" process. If a container is not available in the field to make the test for the presence of gum, a small piece of cane stalk may be placed inside of one's hat which is then replaced on the head for a short time.

If no gum forms from the "sweating" treatment and no red bundles are visible and a variety is still under suspicion a more complete test may be made by planting cuttings from suspected stalks. After 4 or 5 weeks these cuttings are removed from the soil and all discolored tissue carefully cut away. The cuttings are then cut into several short pieces and subjected to the "sweating" treatment. If no exudation of gum appears with this treatment, one may feel satisfied that the original canes were free from the disease.

The gum when examined under the microscope, is found to contain myriads of rod-shaped bacteria. As mentioned before, the gum is formed by the countless numbers of bacteria and is not secreted by the host plant. The bacteria frequently invade the parenchyma tissue near the growing point and cause a rapid breaking down of the tissues giving rise to lysigenous cavities or "gum pockets." When affected stalks are split longitudinally these "gum pockets" are found to vary considerably in size. The cavities are filled with a gummy mass and often such pockets contain practically pure cultures of the organism. In later stages of the disease the tissues of the leaf sheaths frequently become a rusty brown color and are covered with the sticky bacterial slime.

The gum is soluble in water, but insoluble in alcohol; Cobb (8) refers to it as, "a yellowish, non-crystalline, viscid substance having an almost imperceptible acid reaction."

Tissues Affected

The presence of the disease in the stalks is manifested by reddened vascular bundles, especially at the nodes. The disease is largely confined to the vascular system, the vessels of the xylem gradually becoming filled with the bacteria. (See Figs 2, 3, 4 and 5.) The phloem is less frequently affected. The development of

the organism in the plants results in a clogging of the conducting tissues, the normal functions of such tissues being greatly impaired.

Description of the Causal Organism

Erwin F. Smith and others have very carefully described the causal organism. *Bacterium vascularum* is a short rod, 0.4 x 1-1.5 microns, motile, with a single flagellum; no spores have been observed; it is gram positive (but difficult to stain);

Fig. 2. Cross-section of cane leaf affected with gumming, showing bacteria and gum in both xylem and phloem x 370. (Photomicrograph by D. M. Weller.)

pseudo-zoogloeae are formed. It is readily cultured on most nutrient agars. When grown on standard nutrient agar the colonies are pale yellow, smooth, and shining. The organism is strictly aerobic so far as known; optimum temperature, 30° C.; growth retarded at 35° C.; thermal death point 49-50° C. It does not form gas, forms no acid, does not reduce cane sugar and does not reduce nitrates to nitrites.

Transmission

North, in recent studies yet unpublished, has shown the ready transmission of the organism from plant to plant during wet weather, especially if accompanied by winds. Wind causes a considerable amount of mechanical injury to cane foliage due to the serrate edge of one leaf coming in contact with the flat surface of another leaf. During wet weather the gum or exudate oozes freely from diseased foliage and is transferred from leaf to leaf, and stool to stool principally by leaf contacts. The organism gains entrance through the fresh wounds. The organism is unable to penetrate the normal or uninjured cuticle of the leaf and seldom enters

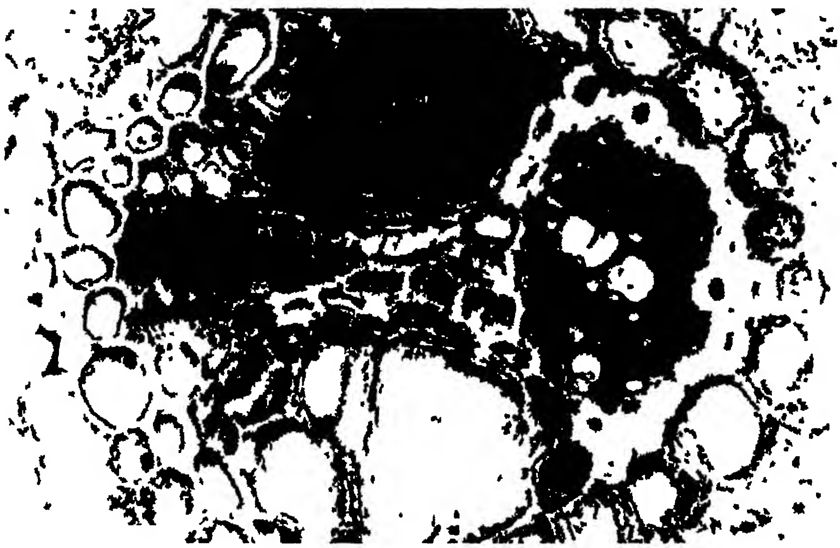

Fig. 3. An enlargement of the bundle shown in Fig. 2, showing in greater detail the discoloration of xylem and phloem due to the occlusion of these tissues by the gum and masses of bacteria, x 565. (Photomicrograph by D. M. Weller.)

through old wounds. Typical leaf streaks may be observed some two to four weeks after infection. The presence of moisture on the leaves is essential for the spread and development of the disease Heavy dews, which often occur during comparatively dry weather, are responsible for a certain amount of spread of the disease.

North has concluded that sucking cane insects are not important in general as agents of transmission, although they may occasionally act as mechanical carriers and may carry the disease for long distances.

The bacteria may be carried by farm implements, especially on cane knives and since the organism is moderately resistant to desiccation it is very probable that the disease is carried from field to field in this fashion.

Control of the Disease

Like all bacterial diseases, gumming presents a complex problem and few control measures, other than resistant varieties, have proved effective. Farm imple-

ments, cane knives, etc., may be treated with an effective disinfectant solution, or exposed to the direct sunlight for short periods before being taken to healthy fields. Roguing is impractical owing to masking of the symptoms. Individual stalks for examination in the fields should be broken off instead of being cut from the stool; this prevents the spread of the disease by knife infection as the same knife may be used during the next five minutes on a healthy stalk which may become inoculated. Preventing the movement of laborers and animals from field to field during wet weather may lessen the spread of the disease. Both in Queensland and New

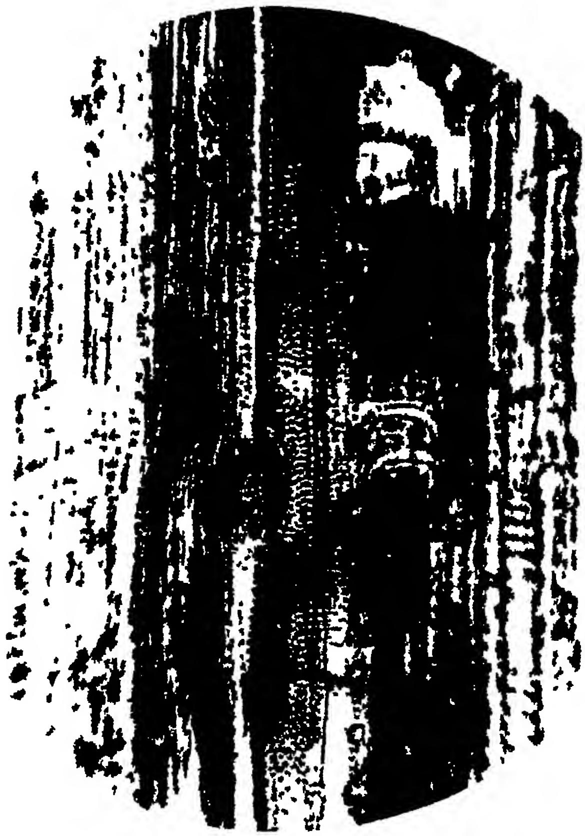

Fig. 4. Longitudinal section of an infected bundle, showing the disorganization of the tissues and the beginning of a lysigenous cavity at x. x 370. (Photomicrograph by D. M. Weller.)

South Wales the disease is less severe on well-drained land than on poorly drained areas.

The greatest success in controlling the disease has been obtained by the use of resistant varieties. A slight reduction in yield may result should the resistant variety be commercially inferior to the susceptible varieties, but when it is possible to have a loss of 60 per cent or more from the disease this reduction is not so serious; the surrounding fields of susceptible canes are also protected.

Since resistant varieties may be diseased and yet exhibit no external symptoms of gumming, it becomes essential to subject all introduced canes, upon their arrival, to contact planting with susceptible commercial canes of the importing country. Such tests should be conducted only under strict quarantine. Since the immersion of diseased cuttings in hot water for one hour at 52° C. results in the death of the organism, the hot water treatment of cane cuttings practically assures the elimination of the disease. The advantage of subjecting imported canes to such a precautionary treatment is self-evident.

Fig. 5. Longitudinal section of cane leaf affected with gumming disease, showing the breaking down or disintegration of the tissue in the xylem. x 565. (Photomicrograph by D. M. Weller.)

Cane Varieties in Relation to Gumming

Under the direction of Mr. North the new cane varieties, in some localities, are often planted in bad gumming areas and within one season the highly resistant ones to the diseases are easily selected, as shown in Figs. 6, 7 and 8. Only the very resistant varieties are tested for their agricultural value. Several of such gumming test plots were visited. In some cases all the plants of a susceptible variety were killed outright while adjacent resistant varieties remained healthy.

Fig. 6. Cane varieties in relation to gumming disease, showing a susceptible variety (left) as compared to a resistant variety (right). Broadwater, N. S. W. (Photo by J. P. Martin.)

Fig. 7. A susceptible variety badly attacked with gumming disease showing scarcity of healthy leaves and sparse growth. Broadwater, N. S. W. (Photo by J. P. Martin.)

Fig. 8. Testing new varieties for gumming resistance. The variety in the foreground has been completely killed, while the variety in the background shows a high degree of resistance to the disease. Broadwater, N. S. W. (Photo by J. P. Martin.)

The following is a list of canes classified according to their resistance to gumming disease which was compiled by Mr. North:

Highly Resistant	Moderately or Commercially Resistant	Susceptible
H. Q. 5	Innis 131	Rose Bamboo
Q. 813	N. G. 16	D. Dupont
Malabar (Yel. Cal.)	D 1135	Lahaina
N. G. 14	Badila	H 109
Korpi	Mahona	
Oramboo	M 1900	
Nanemo or Bogela		
H 227		
China		
Uba		

Summary

1. Gumming disease is considered one of the oldest maladies affecting sugar cane. Severe losses have resulted from its introduction into countries growing commercial varieties that have proved susceptible.

2. Through the importation of diseased cuttings the disease has been spread from one cane country to another. It was first recognized in Brazil in 1869 and now occurs in nine different sugar cane countries of the world.

3. The dwarfing of the plants, striping of the leaves, dying of the tops, reddish bundles in the stalk and the appearance of a yellowish slime or gum on freshly cut surfaces of affected stalks are the conspicuous symptoms of the disease.

4. The gum or exudate is formed by the bacteria and is not a secretion of the host plant. The gum is sticky, soluble in water and is found to contain innumerable rod-shaped bacteria.

5. The transmission of the organism occurs mainly during the wet season and spreads largely by leaf contacts. The organism gains entrance only through fresh wounds. Leaf wounds are formed commonly during wind storms. The presence of moisture on the leaves is necessary for infection of the host and development of the disease.

6. North has concluded that sucking insects are not important as specific agents of transmission although they act as mechanical carriers and may transport the organism for long distances. The bacteria may also be carried on farm implements, cane knives, and animals.

7. New cane varieties should be tested as soon as possible in order to determine their resistance to the disease.

8. The most effective control has been secured through the substitution of resistant varieties. Disinfection of cane knives and implements is also recommended. The immersion of diseased cuttings in hot water for one hour at 52° C. is very effective in killing the organisms. Such a treatment given to all newly imported cane cuttings would largely eliminate the chances of introducing the disease into a country.

Acknowledgments

The writer wishes to express his appreciation for the information so kindly furnished by Mr. North relative to gumming disease. The writer herewith also expresses his appreciation to both Messrs. North and Bell for pointing out the salient facts regarding gumming and other cane diseases occurring in Australia.

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Iron Sulphate Spray for Coral Chlorosis

EWA PLANTATION COMPANY
EXPERIMENT 1, 1929 CROP

By R. E. Doty

This experiment was conducted cooperatively by the Ewa Plantation Company and the Experiment Station, H. S. P. A. This test was in Field 9A, situated in a bad coral area. The layout consisted of eleven watercourse plots of irregular size.

This experiment was harvested previously, for the 1928 crop, and reported by J. A. Verret in the *Planters' Record*, Vol. XXXII, pp. 180-182 (April, 1928). A review of the results of the previous crop is given herewith.

The 1928 crop received one spraynig with a 5 per cent solution of iron sulphate at three months of age. It was harvested on January 6, 1928, at the age of 21.5 months with the following yields:

Yields—1928 Crop	Arith. Average—Adjacent Plots		
	Cane	Q. R.	Sugar
Iron spray	84.12	9.99	8.42
No spray (base)	73.11	9.97	7.33
Gain or loss for sprayed plots	+11.01	—0.02	+ 1.03
Per cent gain or loss for sprayed plots	+15.06	—0.20	+14.87

A 15 per cent gain is noted in favor of the sprayed plots.

The short ratoons harvested in 1929 show a much greater gain (35 per cent), as is given in detail in this report.

The cane was H 109, second ratoons, short, and was 17.4 months old when harvested on June 18, 1929. The crop was started on January 6, 1928. It received two sprayings with a 5 per cent solution of iron sulphate, the first on February 10, 1928, at the age of 1.13 months and the second on March 16, 1928, at the age of 2.3 months.

The labor for the first spraying was at the rate of 0.455 man day per acre and the iron sulphate cost 20 cents per acre.

The second spraying took twice as long and used twice as much material. Total cost of the two sprayings amounted to about $3.00 per acre.

Observations and photographs made on May 10, 1929, showed a marked contrast between the spray and no-spray plots. The stand was good in the sprayed plots and almost a failure in much of the unsprayed area. This effect is the result of saving the stand in the previous crop as well as in the second ratoons. The effect has been decidedly cumulative. The normal plantation replanting was carried out irrespective of treatment but did little for the unsprayed plots. (See Figs. 1 and 2.)

Fig. 1. Iron sulphate spray vs. no spray on young ratoon cane affected with lime-induced chlorosis.
Foreground—No spray.
Background—Sprayed twice with 5 per cent solution of iron sulphate.

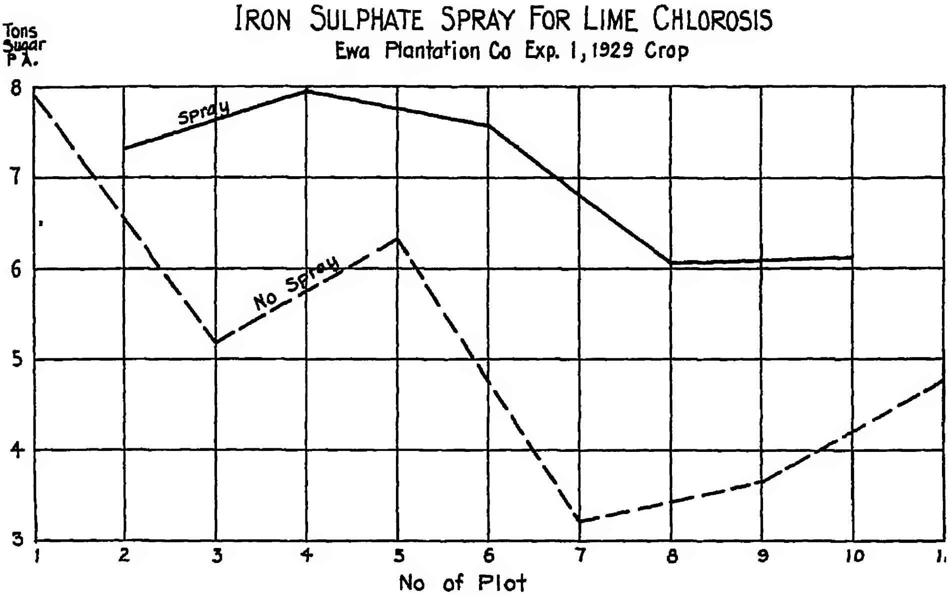


Fig. 2

Ewa Plantation Company computed the results of the 1929 harvest as follows:

SUMMARY OF HARVESTING RESULTS—YIELDS PER ACRE

Treatment	(Arithmetical Average) Cane	Q. R.	Sugar
S—Iron sulphate spray	56.83	8.13	6.99
X—No spray	42.23	8.15	5.18
Gain or loss for sprayed plots..............	+14.60	+0.02	+ 1.81
Per cent gain or loss for sprayed plots........	+34.57	+0.25	+34.94

PLOT TO PLOT COMPARISON

	Total	For S Plots	Same	For X Plots	Odds	Mean Difference Student's Method
Cane	9	8	0	1	1043.4 :1	+15.85
Quality ratio	9	2	4	3	1.77:1	+ 0.03
Sugar	9	2	0	1	832.0 :1	+ 1.97

NITROGEN RATE OF APPLICATION (field application)

	1.83 Mos. Mar. 6/28	3.97 Mos. May 10/28	6.10 Mos. July 14/28	Total Lbs. N.
All plots	53	76	106	235

There is a consistent gain averaging 14½ tons per acre of cane for the treated plots. A biometric analysis by Student's method gives odds of 1043 to 1 against a difference of 15.85 tons of cane being due to chance.

In quality ratio there is no consistent difference between treated and check plots.

The treated plots show an average gain of 1.8 tons of sugar per acre, or a 34.9 per cent gain over checks.

This evidence is quite conclusive that the use of iron sulphate applications in this coral area is warranted and should be employed extensively.

Applications can be made on a field scale at a very low cost per acre compared to the value of the results which accrue.

Notes on Pythium Root Rot

VI

By C. W. Carpenter

Several experiments, in continuation of those cited in "Notes on *Pythium* Root Rot, V"* are discussed in this paper. To recapitulate, root rot of the sensitive Lahaina variety was greatly increased by amending "healthy" soil with stable manure and molashcake. An experiment was mentioned wherein an unsuccessful attempt was made to induce root rot of H 109 by the use of amendments of cane compost. H 109 and Lahaina, as well, grew luxuriantly without root rot in compost alone; Lahaina developed serious root rot, however, in half-and-half mixtures of soil and compost while H 109 had a healthy root system in this as in all mixtures from 20 to 90 per cent compost by volume. It was also mentioned that molashcake amendments greatly aggravated *Pythium* root rot of Lahaina in "sick" Waipio soil, and induced serious root rot of Lahaina in healthy Makiki soil.

It was inferred that Lahaina roots rotted conspicuously when growth was stimulated by amendments of certain materials. H 109 differed from Lahaina in that growth could be greatly stimulated without the occurrence of *Pythium* root rot. The investigation of this point was carried to an extreme in Experiment 112, discussed below, wherein H 109 was grown in pots with soil amended with stable manure.

Experiment No. 112—Effect of Stable Manure on H 109

Sixteen 12-inch pots were prepared with pathology plot soil and stable manure amendments in various amounts by volume as shown in Table I. Cuttings of H 109 were planted November 24, 1928. On February 26, 1929, observations were made and the roots of one plant of each series were washed for examination.

TABLE I

Pot No.	Amendment	Root Rot Feb. 26th (Age 3 Months)	Root Rot May 28th (Age 6 Months)
1-4	Controls	None	None
5-8	25 per cent manure	Moderate	None
9 12	50 per cent manure	Serious	Slight
13-16	75 per cent manure	Serious	Moderate

Appearance of Plants: Control plants were rather pale and restricted in growth, apparently needing more plant food than the unfertilized soil supplied. The plants in the manure amendments were dark green in color, and of larger

* *Hawaiian Planters' Record*, Vol. XXXIII, No. 2, April, 1929, p. 135.

size, except for those in the 75 per cent amendments, which were about the size of the controls. In those soils with larger manure amendments leaf burn and firing of the lower leaves were prevalent.

Root Observations at Three Months. Pot No. 1 Control. The root mass appeared normal for the size of the plant and was characterized by a good development of secondary and tertiary roots and small rootlets. The roots were in general of the fine and wiry type with no large or stimulated roots, such as are common in rich soils.

No. 5. Twenty-five Per Cent Manure. This plant had the largest root mass of the series, characterized by many large, white primary roots, which were mostly healthy. Compared with the control, there were few secondary and tertiary branches, and fine rootlets. A considerable number of the large white roots showed *Pythium* root rot lesions, i. e., yellow to red cankered areas and root tips, many of the latter being flaccid.

No. 9. Fifty Per Cent Manure: Nearly the same root mass was noted as in No. 5, but there was more evidence of *Pythium* injury. Forced branching of the primaries was common following *Pythium* rot of the tips of these roots.

No. 13. Seventy-five Per Cent Manure: Large white primaries were present as in Nos. 5 and 9, but not nearly as numerous. The total root mass was much reduced. Forced branching with large secondaries was common. There were very few small, fine rootlets. *Pythium* rotting of the larger roots with red discoloration was a conspicuous feature, with a flaccid condition of root tips very common on roots of all sizes.

Another series was washed a month later with improved conditions of root health being noticed. The pots were in the open and subject to leaching from rains. On May 28, all remaining units were washed.

Observations: Controls: No. 3; small top as if starving; no stooling; no root rot. No. 4; larger top, with fair green color; two new shoots starting; no root rot.

No. 8. Twenty-five Per Cent Manure: Top much larger than controls, with darker green color, and abundant stooling. Root mass large and filling the pot; no root rot.

Nos. 10 and 12. Fifty Per Cent Manure: The tops were large and green, with good stooling. Roots not quite as well developed as in No. 8 and some showed *Pythium* root rot.

Nos. 15 and 16. Seventy-five Per Cent Manure: The tops were about the same as those of Nos. 10 and 12. There was less stooling than in the 50 per cent manure. Not much of the original root system remained, but there was a predominance of new root growth with some root rot in evidence. These pots seemingly retained enough of the plant food from the manure to stimulate growth, as evidenced by the large white roots, though these latter were at this time not sufficiently hyperstimulated to be readily attacked by *Pythium.*

We infer from this experiment that root growth of H 109 may be stimulated to the point that root rot becomes serious. This requires an excessive amount of plant food. The concentration required to induce susceptibility is so high that it is not likely to occur in the field or to be maintained long if reached accidentally in

localized areas. As soon as the concentration of nutrients becomes reduced as by use of the plant for growth, and leaching, normal root growth is resumed.

Effect of Molasses, Mudpress and Bagasse on Root Rot

In "Notes on *Pythium* Root Rot, V"[*] the effect of molashcake on root rot of Lahaina was discussed. Since this material was so effective in causing root rot of Lahaina in "healthy" soil, experiments were conducted separately on the main ingredients of molashcake to determine which ingredients were the most active. These experiments, Nos. 113, 114, 115, are discussed below. The results are given, in elaboration of the idea that it is the stimulative nature of the amendments that leads to root growth which is susceptible to the attack of *Pythium aphanidermatum*.

Experiment 113—Effect of Molasses on Root Rot

An experiment to test the effect of amendments of molasses, and molasses with sodium nitrate on root rot of Lahaina and H 109 in pathology plot soil, was conducted in 12-inch pots. There were control pots with no molasses, pots with one, two and three pounds of molasses respectively, and a series with the named amounts of molasses plus three grams of sodium nitrate per pot. One-half of the pots were planted with Lahaina and one-half with H 109.

The pots were filled with well mixed pathology plot soil. The molasses and molasses-plus-nitrate pots received the application of the amendments January 4, 1929. All pots were kept moist until March 28, 1929, to facilitate decomposition of the molasses. Planting was done on the latter date, with healthy cuttings from Kailua. Growth was fairly uniform throughout the series with somewhat better foliage color in plants grown in the amended soils. Stooling was also more vigorous in the amended soils. Correlated with this, there appeared to have been a stimulated root growth in the amended soil with serious root rot in the Lahaina, but scarcely a trace in the H 109. The roots of all plants were washed free of soil at the conclusion of the experiment June 25, 1929.

Table II shows the number of pots, treatment of soil three months before planting, cane variety and presence or absence of root rot. Fig. 1 shows the root systems of representative Lahaina plants. The experiment confirms an earlier one in that molasses amendment again induced serious root rot in a soil normally "healthy" for Lahaina cane. Root rot also appeared to be further aggravated by the addition of sodium nitrate to the molasses amendments.

[*] Op. cit.

Fig. 1. Effect of molasses and nitrate of soda amendment on Lahaina roots. No. 1, Control, Lahaina; No. 4, Control, H 109; No. 6, Lahaina, one pound molasses amendment; Nos. 9 10, two pounds; No. 13, three pounds; No. 17, three pounds molasses plus 3 grams sodium nitrate.

TABLE II

Pot No.	Variety	Treatment	Root Rot
1	Lahaina	Control	None
2	Lahaina	"	"
3	H 109	"	"
4	H 109	"	"
5	Lahaina	1 lb. Molasses	Serious
6	Lahaina	"	"
7	H 109	"	Trace
8	H 109	"	None
9	Lahaina	2 lbs. Molasses	Serious
10	Lahaina	"	"
11	H 109	"	None
12	H 109	"	"
13	Lahaina	3 lbs. Molasses	Serious
14	Lahaina	"	"
15	H 109	"	None
16	H 109	"	"
17	Lahaina	1 lb. Molasses, 3 gm. $NaNO_3$	Extreme
18	Lahaina	" "	"
19	H 109	" "	None
20	H 109	" "	"
21	Lahaina	2 lbs. Molasses, 3 gm. $NaNO_3$	(No Germination)
22	Lahaina	" "	Extreme
23	H 109	" "	None
24	H 109	" "	"
25	Lahaina	3 lbs. Molasses, 3 gm. $NaNO_3$	Extreme
26	Lahaina	" "	"
27	H 109	" "	None
28	H 109	" "	"

Experiment 114—Effect of Bagasse on Root Rot

An experiment with pathology plot soil with bagasse, and with bagasse and nitrate of soda amendments was conducted in 12-inch pots. This experiment was designed to reveal the effect of relatively inert organic matter on Lahaina roots. Well mixed pathology plot soil was used. Control soil and amended soil units were prepared as shown in Table III, January 9, 1929. These were kept moist until March 30 or about three months, to allow decomposition, at which time all were planted with healthy Lahaina cuttings from Kailua.

Growth as estimated by size of tops and color of foliage was somewhat depressed in all the amended soils. Stooling was rather poor also in comparison with the controls. The roots were washed free of soil June 25, 1929.

There was no stimulation of root growth such as was found conspicuous in amendments of stable manure, molasses or cane compost, and no root rot. All roots remained of small size, thread-like or fibrous. The controls in pathology plot soil showed a few large roots with some insignificant *Pythium* root rot.

It was noted that the bagasse had not decomposed to any great extent, even in the presence of the nitrate of soda, during the five months of the experiment. The pots were in the open and exposed to rains.

Fig. 2. Effect of bagasse and nitrate of soda amendments on Lahaina roots. No. 11 Control. No. 1, one pound bagasse; No. 5 same as No. 1 plus 3 grams nitrate; No. 7 same as No. 1 plus 5 grams nitrate; No. 10 same as No. 1 plus 10 grams nitrate.

There was no apparent stimulating effect by the amendments, and there was no root rot induced by the bagasse as used. The results were interesting, conversely, since we are assuming as a working hypothesis that it is the hyperstimulated root system which is subject to *Pythium* attack. It also appeared that the bagasse controlled any tendency of the roots to be stimulated by the nitrate. Table III shows the details of the experiment and Fig. 2 shows the root systems of representative units. The better plants and roots were noticed in the controls. The bagasse-plus-nitrogen series was next in order. The plants and roots in soil amended with bagasse alone were noticeably the poorest of all.

TABLE III

Pot No.	Treatment	Root Rot
1	Bagasse 1 lb.	None
2	"	"
3	"	"
4	"	"
5	Bagasse 1 lb., 3 gm. $NaNO_3$	"
6	" "	"
7	Bagasse 1 lb., 5 gm. $NaNO_3$	"
8	" "	"
9	Bagasse 1 lb., 10 gm. $NaNO_3$	"
10	" "	"
11	Control	"
12	"	Trace
13	"	None
14	"	Trace

Experiment 115—Effect of Press Cake on Root Rot

At the same time that the above experiments with molasses and bagasse were started, a simlair experiment was prepared with pathology plot soil and press cake amendments, with and without sodium nitrate. After an incubation period of about three months, the pots were planted with Lahaina cuttings from Kailua, on March 28, 1929.

Table IV shows number of pots, treatment and effect on root *health*. With 1 pound of press cake alone growth of roots as well as tops was moderately stimulated. There was only moderate root rot. With the same amount of press cake plus 3 grams of sodium nitrate, root growth was noticeably more stimulated as indicated by the larger size of roots. There was a conspicuous localization of root rot in the larger roots. With 5 grams of sodium nitrate the root systems were somewhat better, possibly with less root rot at the time observed. With 10 grams of sodium nitrate the roots were very badly reduced by root rot. They had been attacked nearly as fast as they developed and rotted off before they reached a length of six inches. The top was withering, dry and pale and there was a burning and firing of the lower leaves. Throughout the experiment there was a conspicuous firing of the lower leaves with some burning of the edges and tips of young leaves, most marked in pots Nos. 7, 8, 9 and 10.

Fig. 3. Effect of press cake and nitrate of soda amendments on Lahaina roots. Nos. 1 and 4, one pound of press cake. No. 5, same plus 3 grams sodium nitrate; Nos. 7 and 8 same plus 5 grams sodium nitrate. No. 9 same plus 10 grams sodium nitrate; No. 14 control.

Top growth, stooling and root growth were all stimulated by the additions of press cake and press cake plus nitrate of soda. This was accompanied by a tendency to root rot. Fig. 3 shows the root systems of representative units.

TABLE IV

Pot No.	Treatment	Root Rot	Leaf Burn
1	1 lb. Press Cake	Trace	None
2	"	Moderate	"
3	" (No germination)	....	....
4	"	Moderate	None
5	1 lb. Press Cake, 3 gm. $NaNO_3$	"	"
6	" "	Conspicuous	"
7	1 lb. Press Cake, 5 gm. $NaNO_3$	Trace	"
8	" "	Moderate	Present
9	1 lb. Press Cake, 10 gm. $NaNO_3$	Serious	"
10	" "	"	"
11	Control	None	None
12	"	"	"
13	"	"	"
14	"	"	"

Effect of Compost in Sterilized Soil Mixtures

It has been reported* that cane compost in amounts of 20 to 40 per cent by volume induced root rot of Lahaina in "healthy" Makiki soil. To note if compost *per se* exerted any harmful effect, or caused root collapse, mixtures of soil and compost were steam sterilized. Root study boxes were also sterilized and the soil placed therein. The various units and controls as shown in Table V were planted March 30 with Lahaina cuttings from Kailua, which had been cleaned and soaked ten minutes in a 1-1000 solution of mercury bichloride. The cuttings were rinsed thoroughly before planting. Plants were watered throughout the experiment with tap water. As shown in Table V, a parallel series was conducted with comparable mixtures, unsterilized, the cuttings having been similarly disinfected.

TABLE V

Box No.	Soil		Root Rot
1	Makiki soil	Sterilized	None
2	" "	"	"
3	Makiki soil 60 per cent + compost 40 per cent	"	"
4	" " " "	"	"
5	Makiki soil	Unsterilized	"
6	" "	"	"
7	Makiki soil 60 per cent + compost 40 per cent	"	Moderate
8	" " " "	"	"

The roots were washed June 29, 1929. It was significant that although the roots were stimulated in the sterilized soil to better development and formation of larger sized roots than is usual for natural Makiki soil, no root collapse was

* Notes on *Pythium* Root Rot, IV, *Hawaiian Planters' Record*, Vol. XXXII, No. 4, p. 468.

present in the absence of specific organisms. With compost added there was a considerably greater stimulation of root development with large roots predominating, yet no root rot occurred in this sterilized amended soil.

In the unsterilized soil without amendments no root rot occurred. The roots were mostly of the small, fibrous type associated with soils only moderately supplied with nitrogen. With compost, however, in the unsterilized soil the roots were stimulated to better development. Considerable root rot was present in these root boxes (Nos. 7 and 8).

Paralleling the last mentioned experiment with compost, a similar experiment was conducted simultaneously and in the same manner with stable manure. Table VI shows the observations made when the roots were washed after a growing period of three months.

TABLE VI

Box No.	Soil		Root Rot
1	Makiki soil	Sterilized	None
2	" "	"	"
3	Makiki soil 80 per cent, manure 20 per cent	"	"
4	" " "	"	"
5	Makiki soil	Unsterilized	"
6	" "	"	"
7	Makiki soil 80 per cent, manure 20 per cent	"	Serious
8	" " "	"	"

Root rot was found only in the unsterilized soil amended with 20 per cent manure. These units had a very poor root system. In the soil alone, the roots were noticeably darker colored in the unsterilized than in the sterilized soil, but apparently equally healthy.

Olaa Soil Studies

Soil in Field J-2 at the Olaa Sugar Co., Ltd., has proved decidedly unfavorable for Lahaina cane. Soil at Makiki still grows fair Lahaina. Raymond Conant, agriculturist, Olaa Sugar Co., Ltd., collected Olaa soil for the following experiment, which was conducted at Makiki, to note the effect on root health of Lahaina grown in various mixtures of the two soils, i. e., Olaa and Makiki.

Duplicate root study boxes were prepared of Olaa soil and of nine series of dilution, ranging from one-tenth Olaa soil mixed with nine-tenths Makiki soil, to nine-tenths Olaa soil and one-tenth Makiki soil. Table VII shows the arrangement and results observed. The units were planted March 30, 1929, with healthy Lahaina cuttings from Kailua, cleaned, soaked in 1-1000 bichloride of mercury for ten minutes and thoroughly rinsed.

TABLE VII

Box No.	Soil	Germination	Improved Root Health Over Check	Root Rot
1	Control Olaa soil	—		....
2	" " "	+		Bad
3	" " "	+		"
4	" " "	—		....
5A	Olaa soil 9/10, Makiki soil 1/10	+	None	Bad
5B	" " " " " "	+	"	"
6A	Olaa soil 8/10, Makiki soil 2/10	+	"	"
6B	" " " " " "	+	"	"
7A	Olaa soil 7/10, Makiki soil 3/10	+	?	"
7B	" " " " " "	+	?	"
8A	Olaa soil 6/10, Makiki soil 4/10	+	Slight	"
8B	" " " " " "	+	"	"
9A	Olaa soil 5/10, Makiki soil 5/10	+	Marked	Moderate
9B	" " " " " "	+	"	"
10A	Olaa soil 4/10, Makiki soil 6/10	+	"	"
10B	" " " " " "	+	"	"
11A	Olaa soil 3/10, Makiki soil 7/10	+	"	"
11B	" " " " " "	+	"	"
12A	Olaa soil 2/10, Makiki soil 8/10	+	Very marked	Trace
12B	" " " " " "	+	" "	"
13A	Olaa soil 1/10, Makiki soil 9/10	+	" "	"
13B	" " " " " "	+	" "	None
14A	Makiki soil	+	Normal	"
14B	" "	+	"	"

The root systems of this series of plants were washed after a growing period of three months. In the "sick" Olaa soil and in the mixtures wherein this soil predominated over the "healthy" Makiki soil root rot was prevalent. However, there was a rapid decrease of root rot in the series up to the half-and-half mixture, with a more gradual decline as the proportion of healthy soil was further increased. The contrast in root health was particularly marked when the root systems grown in soil mixtures containing more than one-half Olaa soil were compared with those grown in mixtures containing less than one-half Olaa soil. Figs. 4 and 5 illustrate this comparison, the root systems of typical representatives of the series of plants being shown. The relative length and density of roots are shown, though the degree of health or rotting is not discernible in such photographs. Root rot was inconsequential where Olaa soil was present in amounts of 20 to 30 per cent by volume.

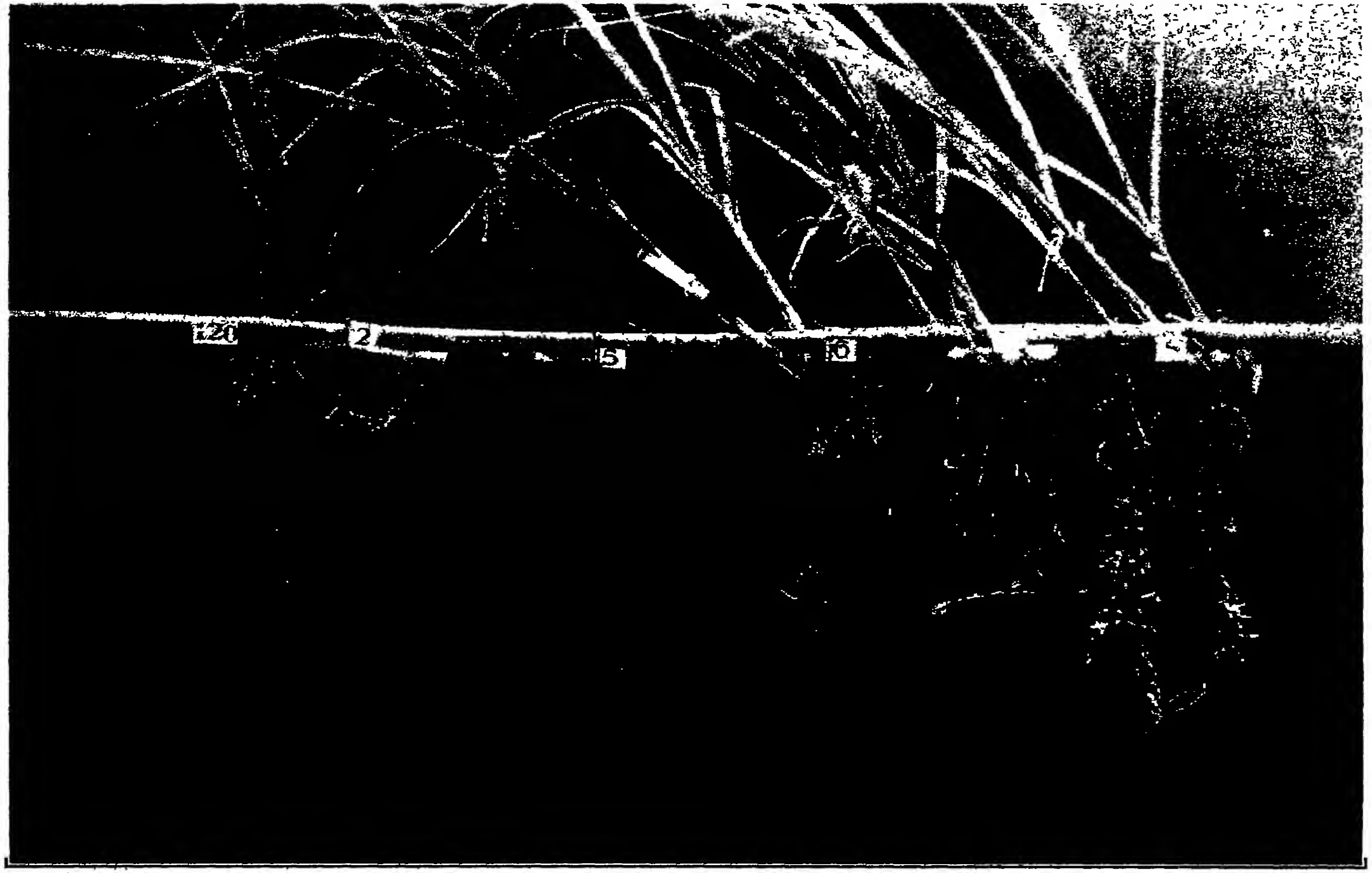


Fig. 4. Effect on Lahaina roots of dilution of Olaa "sick" soil with Makiki "healthy" soil. No. 2, Olaa soil; No. 5, Olaa soil 9/10, Makiki 1/10 by volume; No. 6, Olaa soil 8/10, Makiki soil 2/10; No. 7, Olaa soil 7/10, Makiki soil 3/10; No. 8, Olaa soil 6/10, Makiki soil 4/10.

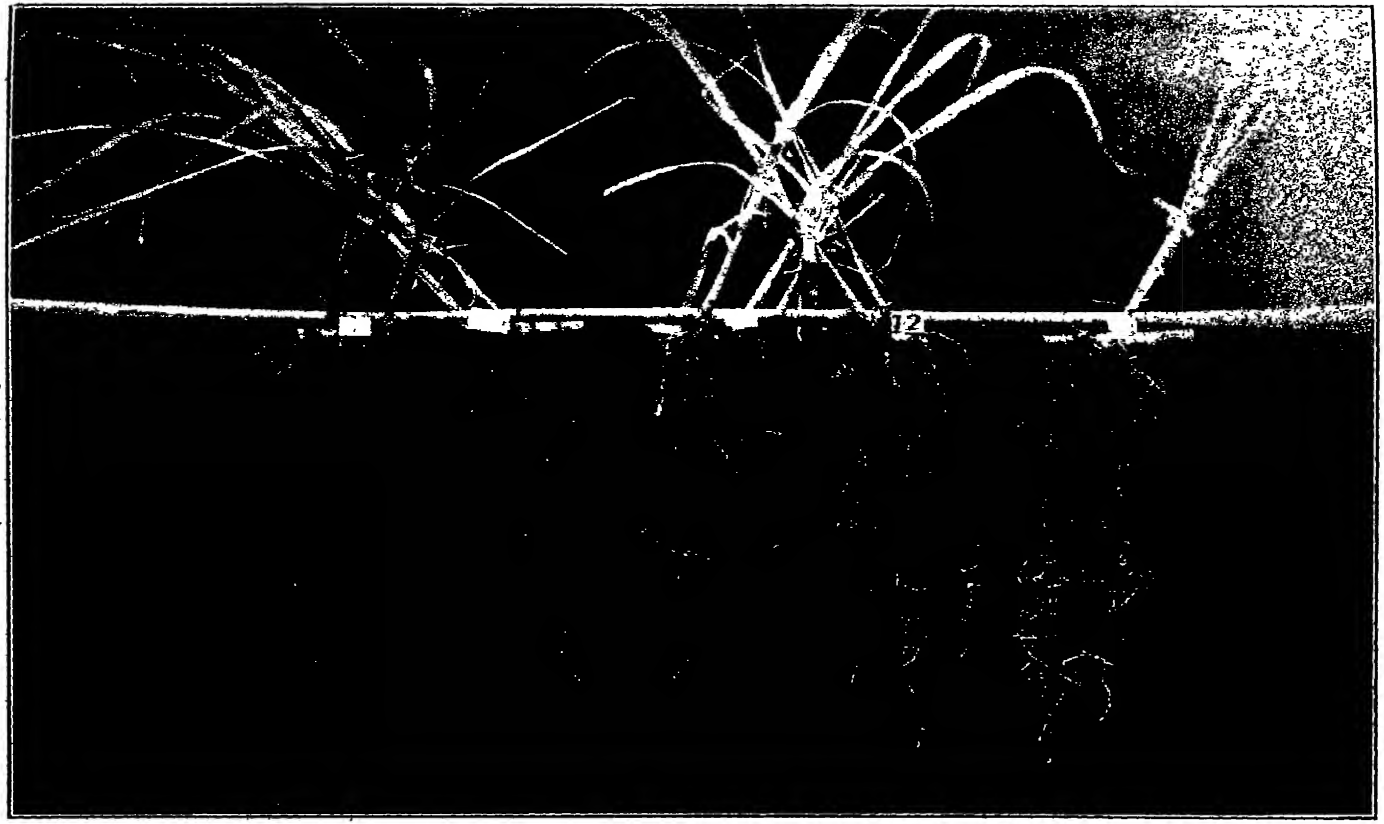


Fig. 5. (Fig. 4 cont.). No. 9, Olaa soil 5/10, Makiki soil 5/10; No. 10, Olaa soil 4/10, Makiki soil 6/10; No. 11, Olaa soil 3/10, Makiki soil 7/10; No. 12, Olaa soil 2/10, Makiki soil 8/10; No. 13, Olaa soil 1/10, Makiki soil 9/10.

Discussion

In an earlier experiment* it was found that when molashcake was allowed to decompose in healthy soil, the latter became a "sick" soil for Lahaina cane; root rot was greatly aggravated in Waipio sick soil by smaller amendments of molashcake. It was found in the present studies that molasses and press cake, the chief nutrients in molashcake, stimulated growth and were active in producing root rot conditions of a healthy soil, while bagasse was not. The latter depressed growth, counteracted any stimulating tendency of the sodium nitrate present, and no root rot occurred. Bagasse might have a useful role as a soil amendment in suitable combinations with molasses to retard disintegration, extend beneficial effects and check any harmful tendencies. That this material can be used as a dry carrier for molasses has been demonstrated by J. A. Verret† and F. E. Hance. Suitable formulae from the viewpoint of desirable biological effects in various soils might be quite different from a mechanical mixture most convenient for field application.

Experiments above cited showed that cane compost or stable manure amendments did not *per se* cause root collapse (Tables V and VI). These materials served as stimulative plant foods, the roots in such steam sterilized amended soil being large and healthy. No root rot occurred, nor any semblance of root collapse. In such amended soils not steamed, *Pythium* root rot was severe. Steam sterilization of a healthy soil has been observed to bring about conditions favorable for root rot, and this disease occurred as soon as *Pythium* was present.

In another experiment, above cited, a "sick" soil was diluted progressively with "healthy" soil, and the effect on the roots of Lahaina observed. As the proportion of "sick' soil decreased root rot became less severe. Improvement in root health was marked when the sick soil was about one-half of the mixture. Root rot all but disappeared in mixtures where the sick soil was but 20 per cent of the whole.

As already reported root rot has been induced in healthy soils by amendments of cane compost, stable manure, molashcake, mud press, molasses and sodium nitrate. These materials, whatever their other characteristics, act as stimulative plant foods. With bagasse amendments, as used, any stimulative tendency of the nitrate of soda present was overbalanced, growth was depressed and no root rot occurred. Traces of root rot did occur in some of the "healthy" soil controls. The Makiki soil is so nearly free of *Pythium* root rot of Lahaina as compared to field soils where this cane suffers severely that it is called "healthy" in these notes.

Accumulated experimental evidence thus shows that a "healthy" soil can be made "sick" for Lahaina cane by stimulative amendments, or by other means of increasing available nutrients, as by steam sterilization and subsequent invasion by *Pythium* species. The harmful accessory factor of *Pythium* in a "sick" field soil can be rendered impotent by dilution of the soil with healthy soil. In view of these

* Notes on *Pythium* Root Rot, V, *Hawaiian Planters' Record*, Vol. XXXIII, No. 2, p. 164.

† Report by J. A. Verret, in Director's Monthly Report, September, 1927; also Proceedings, H. S. P. A., 1927, pp. 89-90.

premises it seems obvious that *Pythium* root rot varies in severity with the concentration of stimulative nutrients.

The theory was advanced* that susceptibility to *Pythium aphanidermatum* was acquired by the roots, and that it was a temporary condition of the root system varying with soil environment. The controlling factor in this acquired susceptibility now appears to be rate and type of growth as determined by stimulative nutrients. The alternate theory, that increased root rot might be due to the stimulative effect of these environments on the fungus, remains to be considered. Experiments may be conducted to learn whether the parasitic tendencies of *Pythium* can be increased by culturing the organism on various stimulative media Since parasitic ability of the *Pythium* cultures has not been a difficulty encountered in experiments over several years, the impression has been gained that root modification was a more logical inference, than variability in the habit of the fungus. It does not appear logical that *Pythium per se* requires 5 per cent of stable manure in a soil to enable it to attack Lahaina, and around 50 per cent of the same amendment to enable it to attack H 109 seriously. The literature supports the view that a too stimulative environment for plants leads to the development of tissues more susceptible to fungus attack.

From a practical viewpoint, if *Pythium* becomes a harmful factor in cane culture only in over stimulative soils, it does not appear very important to know whether the cane, the fungus or both are modified in behavior by the environment.

Summary

1. Serious root rot of H 109 caused by *Pythium aphanidermatum* was induced in a potted soil by amendments of stable manure, 25 per cent to 50 per cent by volume. It is inferred that the observed later resumption of healthy root growth was the result of a reduced concentration of the stimulative nutrients by assimilation and leaching.

2. Root rot of Lahaina was induced in a "healthy" soil by amendments with molasses and mud press respectively. Bagasse, another constituent of molashcake, depressed growth, and no root rot occurred. The previously reported adverse effect of molashcake on root rot was apparently due to the stimulative ingredients, molasses and mud press, and not to the bagasse.

3. No root collapse of Lahaina was found in soil amended with manure or compost and steam sterilized. In such amended soils, not sterilized, *Pythium* root rot was active. Heavy amendment with these materials did not *per se* cause root collapse.

4. When a "sick" soil was diluted progressively with a healthy soil, *Pythium* root rot became less severe. With a half-and-half mixture, a marked improvement of root health was observed. In mixtures containing less than 20 to 30 per cent sick soil, *Pythium* root rot became inconsequential.

* Notes on *Pythium* Root Rot, III, *Hawaiian Planters' Record*, Vol. XXXII, No. 3, pp. 279-288.

5. It is inferred from these experiments that the accessory controlling factor in *Pythium* root rot of Lahaina cane is the type of root growth as determined by stimulative nutrients. Temporarily acquired susceptibility appears to be a function of root nutrition when the nutrients available become too stimulative. In lesser amounts this harmful factor acts as a beneficial soil constituent.

A Comparative Study of the Development of Sugar Cane Roots from Root Primordia

By D. M. Weller

In undertaking a study of the length of life and the duration of the functioning periods of roots of the sugar cane plant, consideration was given to the root primordia, which occur as "root dots" at the base of the internodes of the stems and which, on planted cane cuttings,* develop into "seed-piece roots." In this study consideration was given to the development of these primordia into seed-piece roots and to the time of development of shoot roots in relation to the stage of development of the seed-piece roots for several varieties of cane.

The present experiment (performed in May and June of 1928) was planned to determine (1) the number of root primordia and, therefore, the possible number of seed-piece roots per node for different varieties of cane, (2) the percentage of root primordia "germinating" at stated intervals under field conditions, (3) whether or not any of these root primordia are held in reserve, (4) the time of development of shoot roots in relation to the stage of development of the seed-piece roots, (5) whether or not there exists any correlation between the germination of the root primordia and the development of the buds into shoots, and (6) what variation exists in regard to these points among the varieties H 109, Lahaina, Yellow Caledonia, D 1135, Uba, P. O. J. 213, and P. O. J. 36.

It was impossible to secure cuttings of all of these varieties from the same source and of the same age, but uniform "top seed" of each variety was used. Fifty three-eye cuttings of each of the above mentioned varieties were selected. The number of root primordia of each of the three nodes of each cutting was counted and recorded. The average number per node of the 150 nodes of the seven varieties named above are shown in Table I.

TABLE I

Showing the Average Number of Root Primordia per Node of 50 Three-Eye Cuttings of Several Varieties of Cane

D 1135	122.66
H 109	116.84
Yellow Caledonia	114.43
Lahaina	93.56
P. O. J. 213	45.00
Uba	38.46
P. O. J. 36	29.62

* In Hawaii commonly known as "seed pieces"; in India, as "setts"; in Java, as 'bibits"; in the Philippines, as "points" or "semillas."

It is seen from these figures that there is in regard to this character a great variation among these varieties. No doubt also in any particular variety this character varies greatly with age and growing conditions. This was illustrated by taking at random three sticks of Uba cane from a field other than the one from which the 50 pieces of top seed of this variety were gotten. These sticks were cut off close to the ground and, beginning with the lowest node and proceeding acropetally, the number of root primordia were counted on all nodes of the three sticks. Three sticks each of the varieties D 1135, H 109, and Yellow Caledonia were treated in the same way. The average number of root primordia per node for the three sticks of these four varieties was as follows:

Yellow Caledonia	220.09
H 109	95.66
D 1135	83.80
Uba	39.16

A comparison of these data with those of Table I shows that great variation exists within the variety also and suggests that possible correlations exist between these numbers and age of cane, season, nutrition, pH of soil, etc. The discovery of such correlations would be profitable provided it can be shown that *for a given variety* either quickness of germination of the buds, or "stand" of cane is dependent upon the number of these root primordia. Of course between the varieties there is no such correlation as is evidenced by Figs. 1 to 4.

Plan of the Experiment

When the number of root primordia on the 50 three-eye cuttings of each of the seven varieties named above were recorded, the cuttings were planted at random in the field and irrigated at the rate of one acre-inch of water every 5 days.

The 50 cuttings of each variety were divided into five groups of 10 each. Those of each variety belonging to Group I, were removed from the ground 5 days after they were planted, the number of developing root primordia on them counted and recorded and the percentage this number was of the total number of root primordia calculated. (Fig. 1.)

The number of shoot roots was also recorded. All developing roots were then cut off close to their proximal ends and the seed pieces replanted. At the end of a second period of 5 days in the ground these seed pieces were again removed from the soil and the number of developing roots counted and cut off as before. This operation was repeated at intervals of 5 days for 50 days.

The seed pieces of each variety belonging to Group II were treated as were those of Group I except that they were taken up and replanted at intervals of 10 days for 50 days. (Fig. 2.)

Group III was treated in the same way at intervals of 15 days, Group IV at intervals of 25 days (Fig. 3), Group V at the end of one interval of 50 days (Fig. 4). The irrigations were so timed as to be given immediately after every planting.

The number of seed-piece roots counted in this way is recorded in Table II.

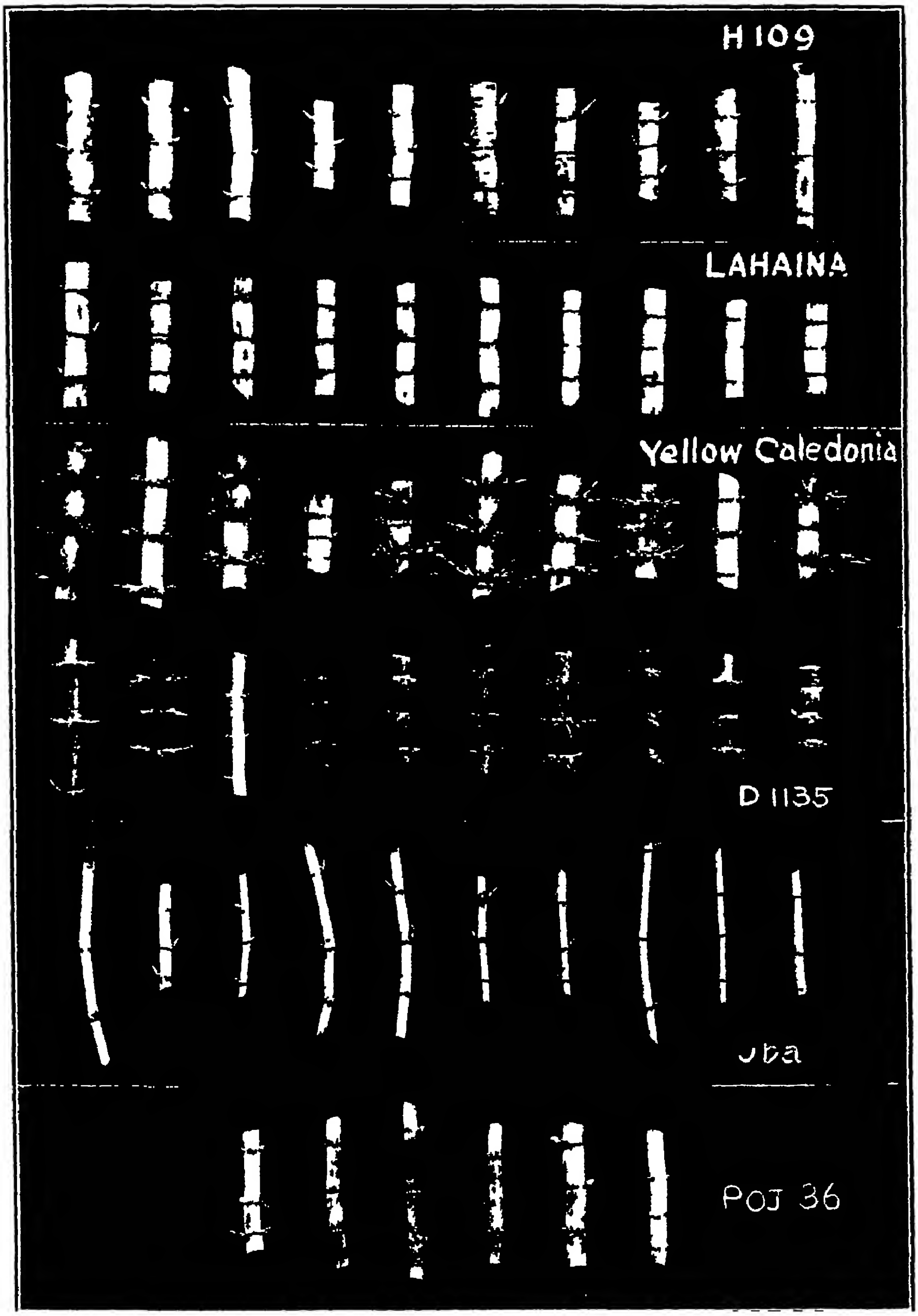


Fig. 1. Showing the relative development of seed-piece roots from the root primordia, or "root dots," the stage of development of the "eyes" into the shoots, and the general appearance of seed pieces of Group I after being planted in the ground for the first of ten 5-day periods, and receiving irrigation water at the rate of one acre-inch when planted.

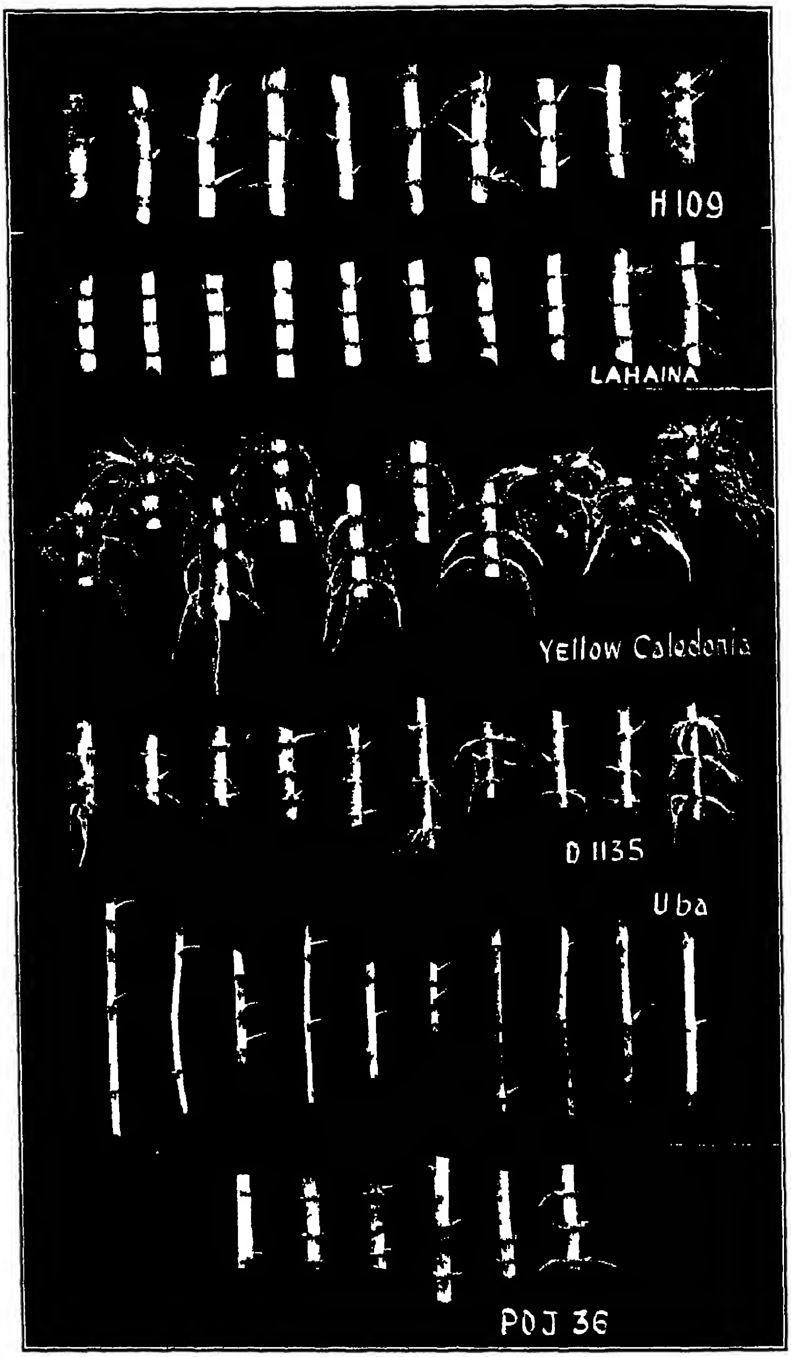


Fig 2 Showing the relative development of seed piece roots and shoots from the seed pieces of Group II after being planted in the ground for the first 10 day period and being irrigated once when planted and once 5 days later at the rate of one inch per acre

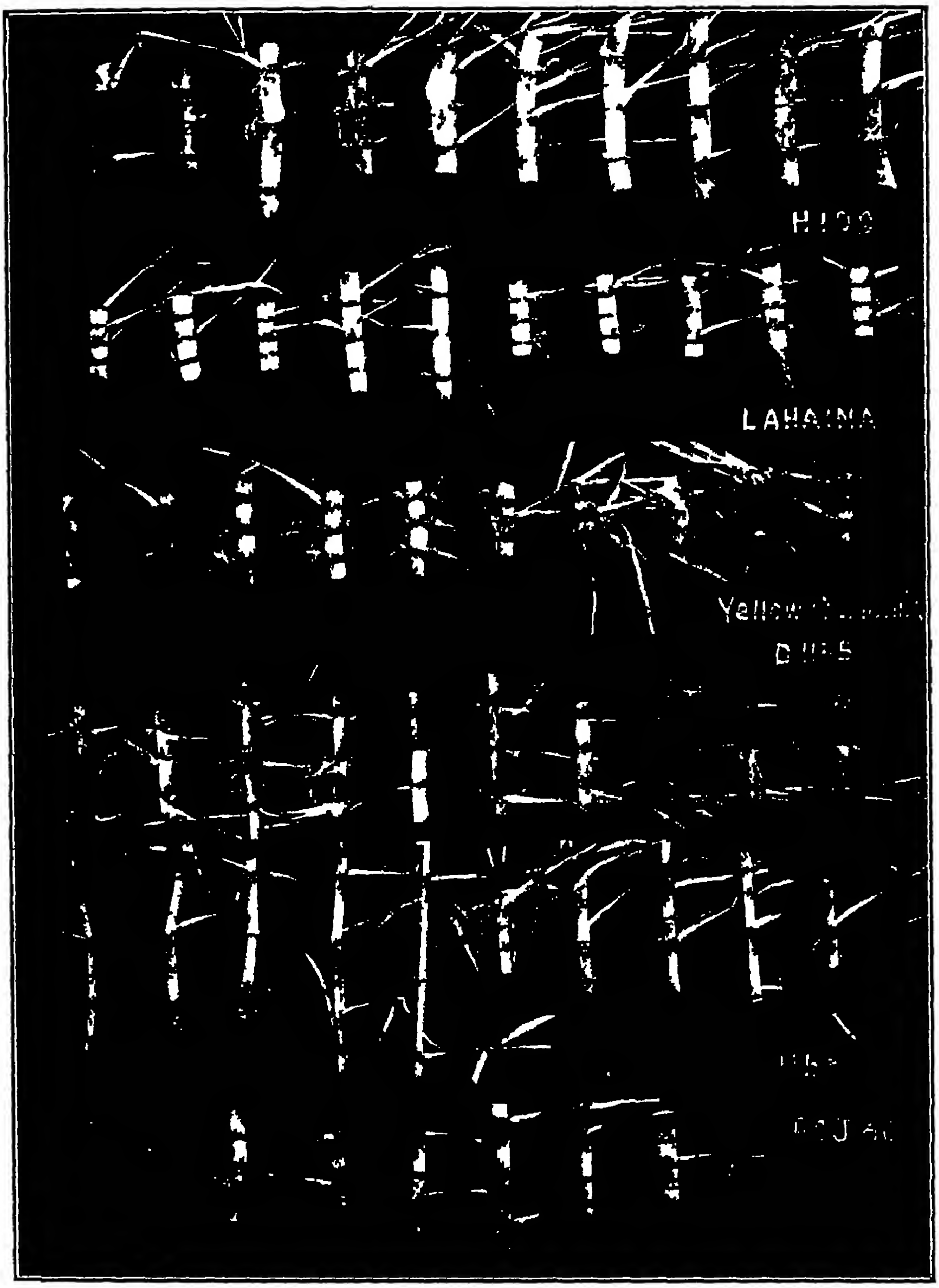


Fig 8 *Showing the relative development of seed piece roots and shoots from the seed pieces of Group IV after being planted in the ground for the first 25 day period and receiving five rounds of irrigation water at the rate of one acre inch every 5 days*

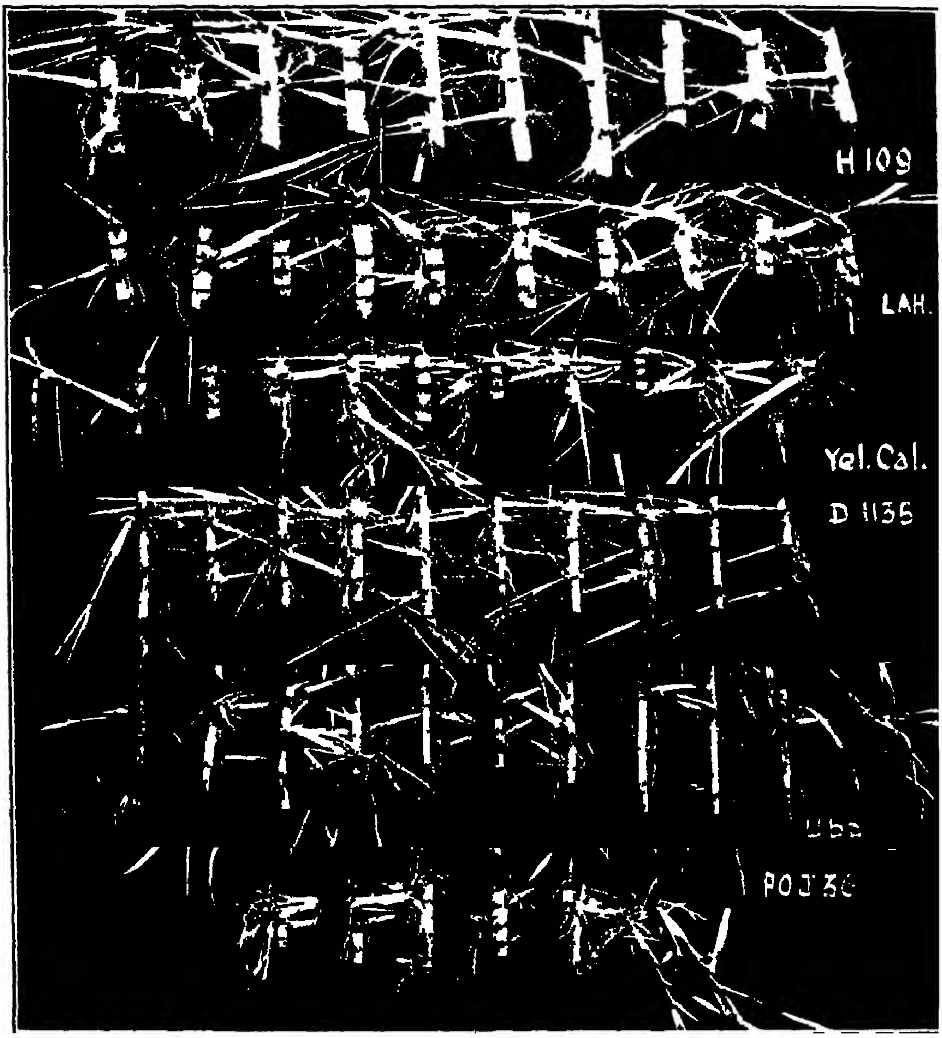


Fig 4 Showing the relative development of seed piece roots and shoots from the seed pieces of Group V after being in the ground "undisturbed" for a period of 50 days and receiving ten irrigations at the rate of one acre inch every 5 days

TABLE II

Showing the number of root primordia for each group of cuttings of the seven varieties of cane, and both the number and the per cent of these primordia developing into seed-piece roots after each interval of 5, 10, 15, 25, and 30 days

Group	No. of Seed Pieces	Variety	No. of Root Primordia	5 No.	5 %	10 No.	10 %	15 No.	15 %	20 No.	20 %	25 No.	25 %	30 No.	30 %	35 No.	35 %	40 No.	40 %	45 No.	45 %	50 No.	50 %	TOTAL No.	TOTAL %
				DAYS AFTER PLANTING																					
I	10	H 109	3829	139	3.6	751	19.6	445	11.6	160	4.1	143	3.7	11	0.2	11	0.2	0	0.0	0	0.0	1	0.02	1603	43.4
	10	Lahaina	3016	105	3.4	273	9.0	248	8.2	146	4.8	453	15.0	310	10.2	51	1.6	39	1.2	3	0.09	1	0.03	1629	54.0
	10	Yel. Cal.	4438	2871	64.6	474	10.6	244	5.4	100	2.2	103	2.3	82	1.8	32	0.7	73	1.6	19	0.4	2	0.04	4000	90.1
	10	D 1135	3692	1648	44.6	487	13.1	305	8.2	44	1.1	28	0.75	29	0.78	1	0.02	0	0.0	0	0.0	0	0.0	2542	68.8
	10	Uba	1059	63	5.9	64	6.0	99	9.3	15	1.4	70	6.6	12	1.1	0	0.0	1	0.09	0	0.0	0	0.0	324	30.5
	10	P. O. J. 213	1369	445	32.5	121	8.8	168	12.2	20	1.4	68	4.9	23	1.6	1	0.07	3	0.2	9	0.6	0	0.0	858	62.6
	10	P. O. J. 36	1441.6*	973.3	67.8	145.0	10.1	126.6	8.8	0	0.0	10	0.6	3.3	0.2	3.5	0.2	0	0.0	0	0.0	0	0.0	1261.5	87.5
II	10	H 109	3346			1146	34.2			764	2.8			87	2.6			27	0.8			17	0.5	2041	60.9
	10	Lahaina	2804			553	19.7			464	8.5			386	13.7			101	3.6			66	2.3	1570	55.9
	10	Yel. Cal.	3459			2711	78.3			478	3.8			95	2.7			8	0.2			5	0.1	3297	95.3
	10	D 1135	3734			1288	34.4			710	9.0			147	3.9			26	0.6			4	0.1	2175	58.2
	10	Uba	1285			173	14.0			157	2.7			85	6.8			17	1.3			1	0.08	433	35.0
	10	P. O. J. 213	1505			729	48.4			351	23.3			24	1.5			4	0.2			1	0.06	1109	73.6
	10	P. O. J. 36	1600.0*			920	57.5			300	8.7			66.6	4.1			0	0.0			8.3	0.5	1294.9	80.9
III	10	H 109	3668					1329	36.2					289	7.8					10	0.2			1628	44.3
	10	Lahaina	2825					709	25.0					672	23.7					64	2.2			1445	51.1
	10	Yel. Cal.	3274					2215	67.6					544	16.6					9	0.2			2768	84.5
	10	D 1135	3534					1688	47.7					322	9.1					9	0.2			2019	57.1
	10	Uba	1312					261	19.8					193	14.7					21	1.6			475	36.2
	10	P. O. J. 213	1287					556	43.2					241	18.7					8	0.6			805	62.5
	10	P. O. J. 36	1523.3*					923.3	60.6					226.6	14.8					0	0.0			1149.9	75.4
IV	10	H 109	3296									1109	33.6									343	10.4	1452	44.0
	10	Lahaina	2653									629	23.6									173	6.5	802	30.2
	10	Yel. Cal.	3021									2380	78.7									196	6.4	2576	85.2
	10	D 1135	3955									1642	41.5									113	2.8	1755	44.3
	10	Uba	1138									410	36.0									77	6.7	487	42.7
	10	P. O. J. 213	1312									875	66.6									68	5.1	943	71.8
	10	P. O. J. 36	1520.0*									853.3	56.1									110	12.0	622	68.1
V	10	H 109	3387																			1213	35.8	1218	35.8
	10	Lahaina	2737																			746	27.2	746	27.2
	10	Yel. Cal.	2973																			1879	63.2	1879	63.2
	10	D 1135	3484																			1847	53.0	1847	53.0
	10	Uba	1026																			302	29.3	302	29.3
	10	P. O. J. 213	12078																			842	65.8	842	65.8
	10	P. O. J. 36	1326.6*																			941.6	70.9	941.6	70.9

* Because only six seed pieces of P. O. J. 36 were used in each group the counts for this variety were multiplied by 10/6 to make the data comparable with that for the other varieties.

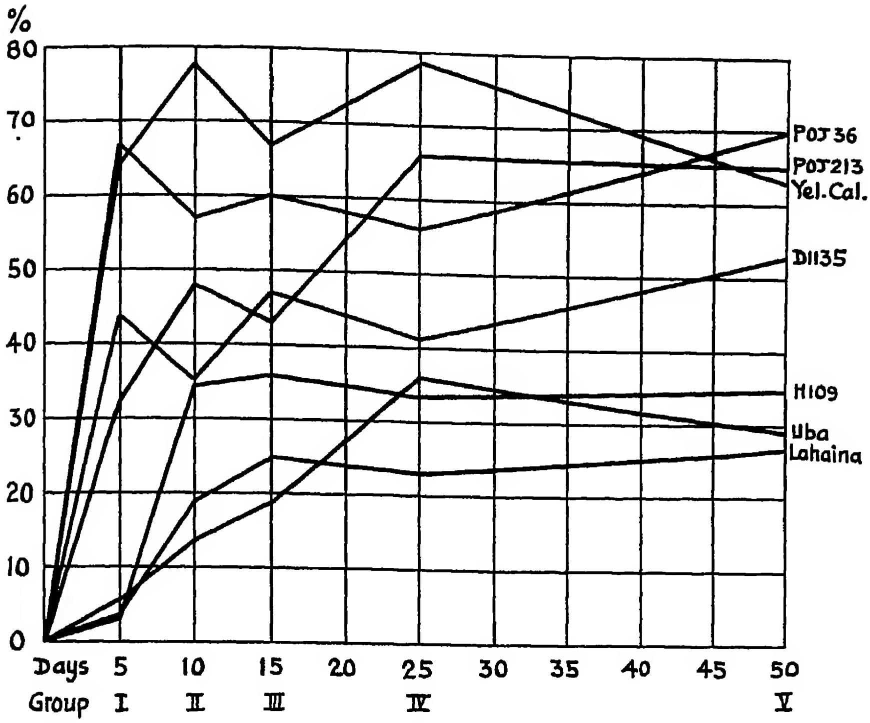


Fig. 5. Showing the percentage of root primordia developing into seed-piece roots on the five groups of seed pieces after being planted in the ground for the first period of 5 days (Group I), 10 days (Group II), 15 days (Group III), 25 days (Group IV), and 50 days (Group V).

The number and percentage of root primordia developing into seed-piece roots varied with the variety as is shown in Table II. From the data of Table II can be seen the number and per cent of root primordia developing into seed-piece roots at the end of the several periods. At the end of 5 days, for example, on the H 109 seed pieces of Group I, 139 root primordia, or 3.6 per cent of the total had developed into seed-piece roots, while on the Yellow Caledonia 2871, or 64.6 per cent, had developed into seed-piece roots. After being in the ground undisturbed for 50 days there had developed, on the Lahaina seed pieces of Group V, 746 seed-piece roots, or 27.2 per cent, while on those of the D 1135 of the same group 1847, or 53.0 per cent, had developed. Other varieties for these two periods as well as for other periods can be compared.

From Table II it can also be seen that, in general, after a period of 50 days the percentage of root primordia developing into roots was very little higher, if any, than the percentage developing in from 10 to 25 days. This is shown graphically in Fig. 5.

Root Primordia Held in Reserve

A comparison of the number of root primordia developing into seed-piece roots from the seed pieces undisturbed for 50 days with the number developing from those taken out and replanted at stated intervals is shown in Table III.

TABLE III

Showing the total per cents of the root primordia developing into seed-piece roots from the seed pieces undisturbed for 50 days, and for those disturbed at intervals of 5, 10, 15, and 25 days for 50 days. The figures opposite these per cents (in parentheses) followed by plus or minus signs indicate how much these total per cents were above or below the "average for the disturbed" seed pieces.

VARIETY	UNDISTURBED 50-Day Interval %	DISTURBED 5-Day Intervals %	DISTURBED 10-Day Intervals %	DISTURBED 15-Day Intervals %	DISTURBED 25-Day Intervals %	Average for Disturbed %
H 109	35.8 (12.3—)	43.4 (4.7—)	60.9 (12.8+)	44.3 (3.8—)	44.0 (4.1—)	48.1
Lahaina	27.2 (20.6—)	54.0 (6.2+)	55.9 (8.1+)	51.1 (3.3+)	30.2 (17.6—)	47.8
Yellow Caledonia	63.2 (25.5—)	90.1 (1.4+)	95.3 (6.6+)	84.5 (4.2—)	85.2 (3.5—)	88.7
D 1135	53.0 (4.1—)	68.8 (11.7+)	58.2 (1.1+)	57.1 (0.0)	44.3 (12.8—)	57.1
Uba	29.3 (6.8—)	30.5 (5.6—)	35.0 (1.1—)	36.2 (0.1+)	42.7 (6.6+)	36.1
P. O. J. 213..	65.8 (1.8—)	62.6 (5.0—)	73.6 (6.0+)	62.5 (5.1—)	71.8 (4.2+)	67.6
P. O. J. 36............	70.9 (7.0—)	87.5 (9.6+)	80.9 (3.0+)	75.4 (2.5—)	68.1 (9.8—)	77.9

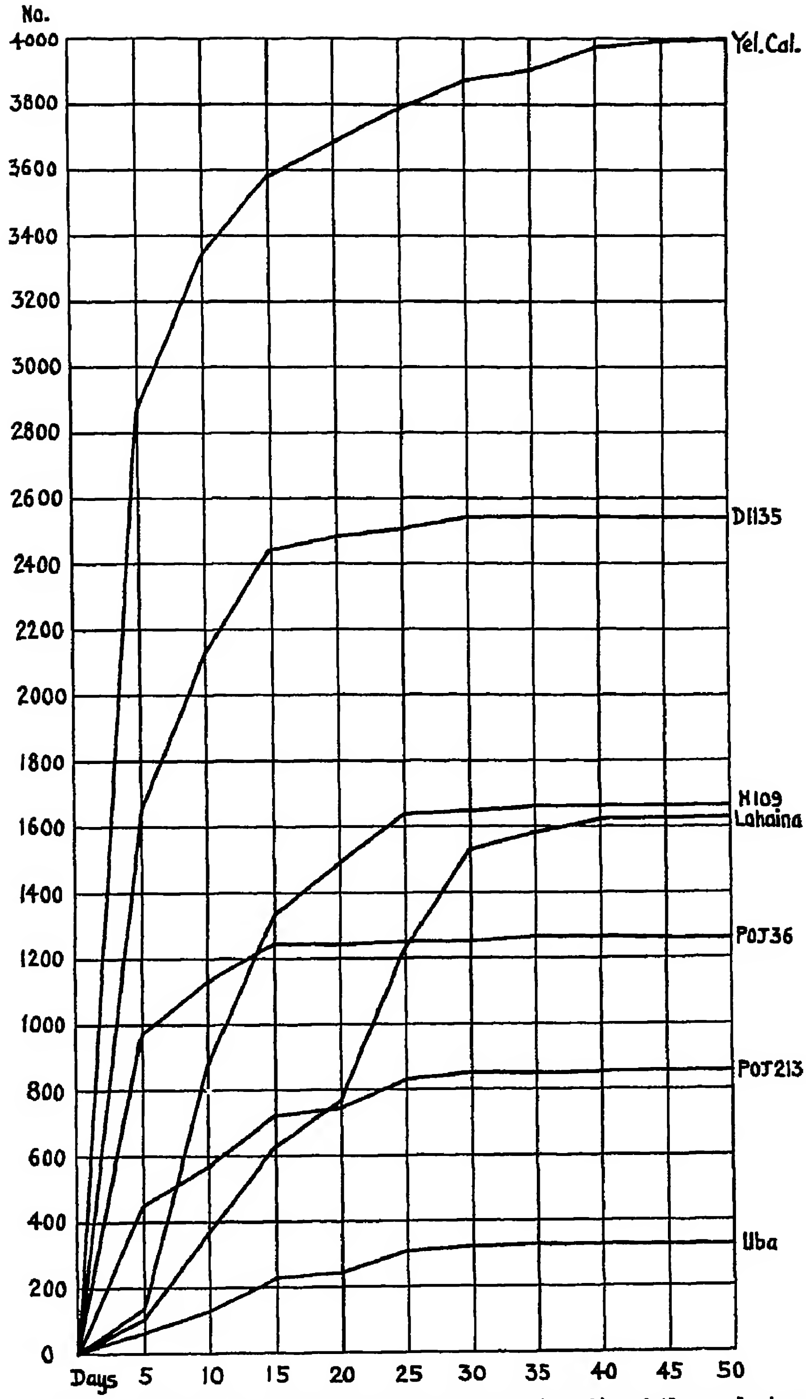


Fig. 6. Showing the total number of root primordia of the seed pieces of Group I which had developed into roots at the end of each of the ten 5-day periods.

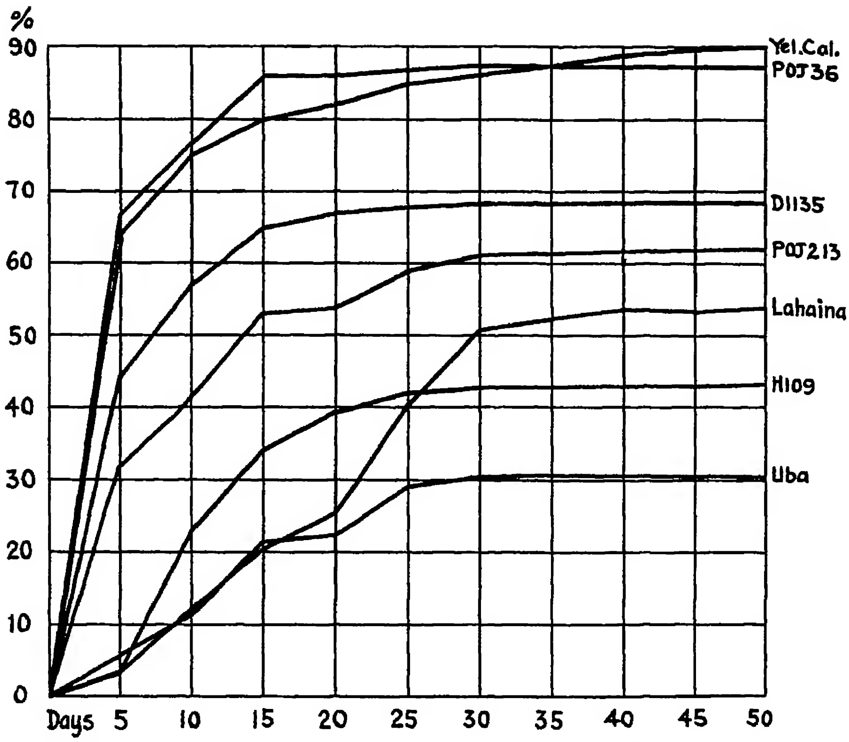


Fig 7. Showing the total percentage of root primordia of the seed pieces of Group I which had developed into roots at the end of each of the ten 5 day periods.

It is interesting to note that in every case the total per cent of root primordia developing into seed-piece roots on the seed pieces left undisturbed for 50 days was less than the *average* of the total per cents of those removed from the ground and replanted at intervals of 5, 10, 15 and 25 days for 50 days, this difference being greatest for Yellow Caledonia, namely 25.5 per cent. This would indicate that, when the developed roots were cut off, *other primordia developed which under normal conditions would not have done so.* In other words *a certain number of root primordia is held in reserve and develop only in case of need* (Figs. 6 and 7).

For this reason the curves of Figs. 6 and 7 have a persistent tendency to rise continuously up to the fiftieth day, which is in contrast to the tendency of the curves of Fig. 5 to level off after the first 5 days. This may find practical application in the practice of off-barring and sub-soiling and will be discussed more fully in connection with the development of roots from the shoots.

From the graphs of Figs 8 and 9 can be seen how the total number and percentage of root primordia developing into roots is greater for seed pieces "disturbed" over a period of 50 days at intervals of 5 or 10 days than for those "disturbed" at intervals of 15, 25 or 50 days. In the case of Uba, however, there is seen to be a slight deviation from this tendency. In Fig. 10, this fact is shown still more clearly for the variety Yellow Caledonia.

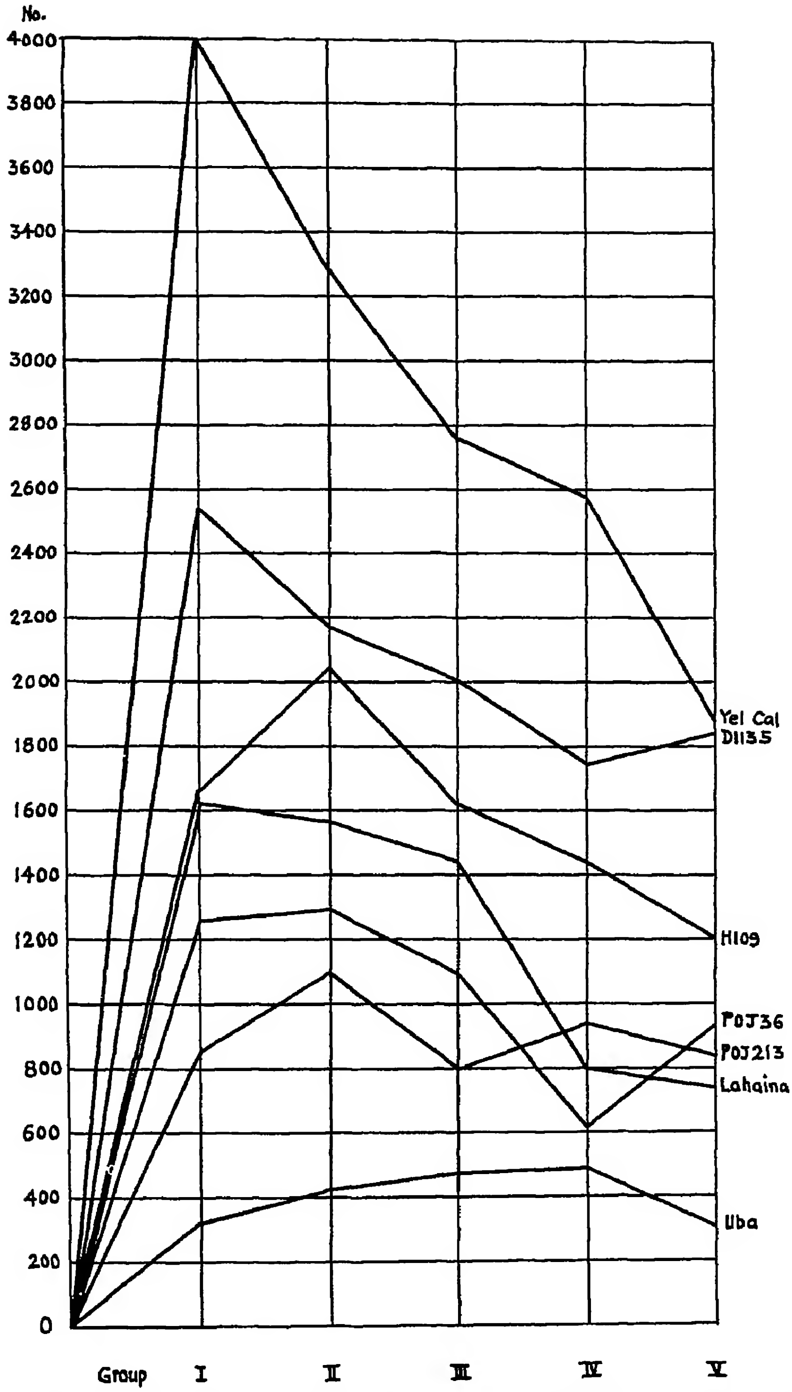


Fig. 8. Showing the total number of root primordia developing into roots at the end of ten 5 day periods (Group I), five 10-day periods (Group II), three 15-day periods (Group III), two 25 day periods (Group IV), and one 50-day period (Group V).

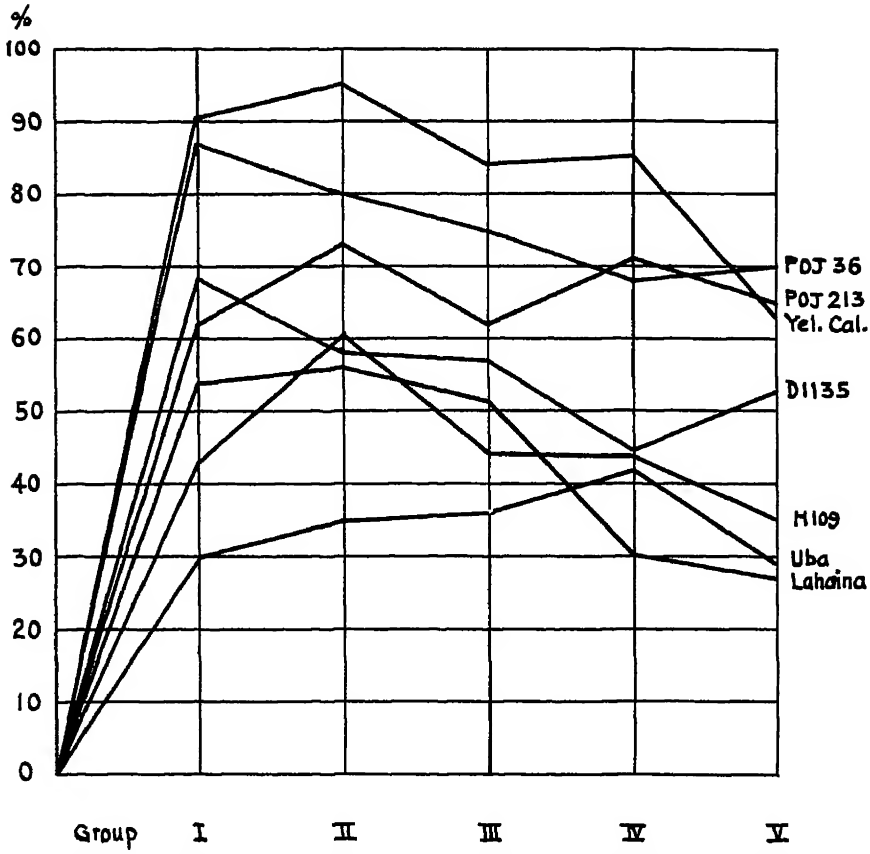


Fig. 9. Showing the total percentage of root primordia developing into roots at the end of ten 5 day periods (Group I), five 10-day periods (Group II), three 15-day periods (Group III), two 25 day periods (Group IV), and one 50 day period (Group V).

The Development of Shoot Roots

It has been shown that the seed-piece roots of the cane plant function only until the shoot develops from the bud and puts out roots of its own.* A bud from which such a shoot develops is essentially a miniature shoot with greatly shortened internodes and nodes bearing scales instead of leaves. In the axils of these bud scales are root primordia just as there are root primordia on the root band (Keimring) of the mature shoot. It is not surprising, therefore, to find shoot roots developing and pushing out from between the bud scales even when the internodes of the bud have only begun to lengthen.

When the seed pieces of Group I were dug up after the first 5-day period in the ground, from between the scales of some of the buds on seed pieces of Yellow Caledonia shoot roots had already developed. These roots are scarcely distinguishable from the seed-piece roots in Fig. 1.

* Lee, H. Atherton, and Weller, D. M. 1927. The Length of Life of Seed-Piece Roots and the Progress of Sugar Cane Roots in the Soil at Different Ages of Growth. The Hawaiian Planters' Record, Vol. XXXI, pp. 25-35.

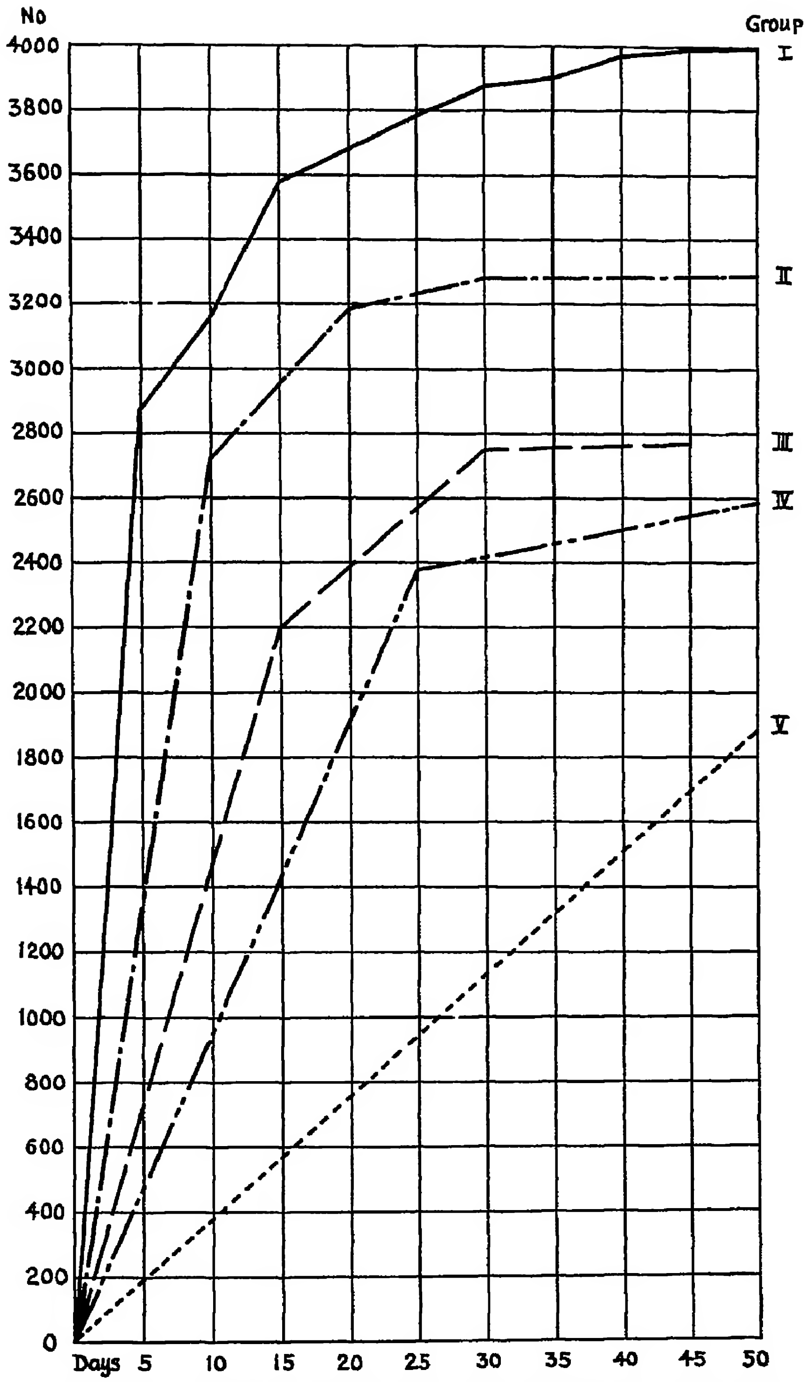


Fig. 10. Showing the number of root primordia of Yellow Caledonia developing into roots on seed pieces dug up, the developing roots cut off, and the seed pieces replanted at intervals of 5 days (Group I), 10 days (Group II), 15 days (Group III), 25 days (Group IV), and 50 days (Group V), for 50 days.

In Fig. 11 is shown a node of a seed piece of the variety P. O. J. 36 at the end of the second 5-day period in the ground. In the illustration it can be seen where, at the end of the first 5-day period, the seed-piece roots which had developed from this node were cut off. At the time the photograph was taken no additional seed-piece roots had developed from the root primordia held in reserve.

The record of this particular node shows that at the end of the second 5-day period 96 of its 127 root primordia had developed into roots but that, after shoot roots began to develop from the bud of this node, even after eight additional 5-day periods in the ground, only four more root primordia of this node developed into roots.

Fig. 11. Showing a seed piece of the variety P. O. J. 36, the buds of which had put out shoot roots by the end of the second 5 day period in the ground (Group I).

After the first 5-day period in the ground the buds of the seed pieces of Group I showed this condition with increasing frequency. This demonstrates how early the young cane plant (developing bud) may begin its own independent existence, which is practically complete at about the fourth month.* There is no doubt, however, that this character varies with the variety and is greatly influenced by temperature and moisture. In Figs. 1 to 4 can be seen how these shoot roots developed on other groups.

Counts were made of the number of shoot roots developing from shoots on the several groups of seed pieces as they were taken out of the ground at the various intervals. These are shown in Table IV.

* Lee and Weller, Op. cit.

TABLE IV

Showing the total number of shoot roots developing from shoots on the group of seed pieces left undisturbed in the ground for 50 days and on the groups disturbed at intervals of 5, 10, 15, and 25 days. The figures (in parentheses) opposite these numbers followed by plus or minus signs indicate how much these totals were above or below the average for the disturbed seed pieces.

VARIETY	UNDISTURBED 50-Day Interval	DISTURBED 5-Day Intervals	10 Day Intervals	15-Day Intervals	25-Day Intervals	Average for Disturbed
H 109	86 (28.3+)	24 (33.7—)	59 (1.3+)	61 (3.3+)	87 (29.3+)	57.7
Lahaina	240 (114.8+)	72 (53.2—)	135 (9.8+)	138 (12.8+)	129 (3.8+)	125.2
Yellow Caledonia	329 (138.8+)	247 (56.8+)	133 (57.2—)	186 (4.2—)	195 (4.8+)	190.2
D 1135	234 (12.0+)	193 (29.0—)	307 (85.0+)	212 (10.0—)	176 (46.0—)	222.0
Uba	627 (206.5+)	309 (111.5—)	391 (29.5—)	396 (24.5—)	596 (175.5+)	420.5
P. O. J. 213...	626 (312.8+)	187 (126.2—)	292 (21.2—)	393 (79.8+)	381 (67.8+)	313.2
P. O. J. 36_2..........	643.3 (381.4+)	341.3 (20.6—)	298.1 (63.8—)	426.6 (64.7+)	381.6 (19.7+)	361.9

From the data of Table IV it is seen that when the seed peices of the variety H 109 were taken out, the developing roots cut off, and replanted at intervals of 5, 10, 15 and 25 days the number of shoot roots averaged 57.7 for these four groups. Those left undisturbed in the ground for 50 days developed 86 shoot roots, or 28.3 more for the undisturbed than for the *average* of the disturbed. On the seed pieces of Yellow Caledonia undisturbed for 50 days 329 shoot roots developed, or 138.8 more than the average for the disturbed seed pieces. From these data it is seen that for every variety examined the number of shoot roots developing on shoots from seed pieces undisturbed for 50 days *exceeded* the average of those developing on shoots from seed pieces disturbed at intervals of 5, 10, 15 and 25 days for 50 days. This is in contrast with the data of Table III, where, without exception, for the same varieties the percentage of seed-piece roots developing on seed pieces undisturbed for 50 days *was less* than the average of those developing on seed pieces disturbed at intervals of 5, 10, 15 and 25 days for 50 days.

As was mentioned above, these facts may well find practical application in the practice of off-barring and sub-soiling. As was shown by the contrasted data of Tables III and IV *the "pruning" of the seed-piece roots stimulated into development root primordia of the seed pieces which under normal conditions would have been held in reserve. The "pruning" of the shoot roots resulted only in fewer roots being developed from these shoots.* Inasmuch as the cane plant (developing shoot) ultimately relies upon its own shoot roots, the "pruning" of these shoot roots can result in only seriously handicapping its normal development.

The relationship which exists between old ratoon roots and the roots developing from the new ratoon shoots would be expected to be similar to that of the functioning seed-piece roots to the developing shoot roots of the plant crop.*

Off-barring and sub-soiling, therefore, which are done early enough to avoid cutting off roots from the shoots and to so cut away the old root mass as to make water, fertilizer, and air more easily available to the developing shoot roots should result only in benefit. Off-barring and sub-soiling which is done so late as to injure developing shoot roots can result only in harm.

Summary

1. A study was made of the development of the roots of the sugar cane plant from the root primordia, which occur as "root dots" on the "root bands" (Keimring) at the base of the internodes of the stems.

2. The number of root primordia and, therefore, the possible number of seed-piece roots per node differed greatly for the varieties studied.

3. Fifty cuttings of the variety H 109 were divided into 5 groups of 10 cuttings each and planted in the ground for 50 days. The 10 cuttings of Group I were removed from the soil every 5 days, and after the number of seed-piece roots developing on them had been recorded and cut off, they were replanted. The 10

* An experiment now in progress to determine this relationship between ratoon roots and roots from the ratoon shoots seems to confirm this statement.

cuttings of Group II were treated in the same manner as were those of Group I at intervals of 10 days, those of Group III were treated in the same way at intervals of 15 days, those of Group IV at intervals of 25 days, and those of Group V at the end of one period of 50 days. The number of shoot roots produced by the developing shoots was also recorded. Irrigations were given every fifth day at the rate of one inch per acre and were so timed as to be given immediately after each group was replanted. The varieties Lahaina, Yellow Caledonia, D 1135, Uba, P. O. J. 213 and P. O. J 36 were also studied.

4. The number and per cent of the root primordia developing into seed-piece roots at different periods of time were determined. At the end of the first 5-day period, for example, on the ten H 109 seed pieces of Group I, 139 root primordia, or 3.6 per cent of the total, had developed into seed-piece roots, while on the Yellow Caledonia of the same group 2871, or 64.6 per cent, had developed.

5. The percentage of root primordia developing into seed-piece roots on seed pieces planted for 50 days is very little higher, if any, than for seed pieces planted for from 5 to 25 days.

6. A certain number of root primordia are held in reserve and develop only in case of need. The total per cent of root primordia developing into seed-piece roots was less for seed pieces left in the ground undisturbed for 50 days than for seed pieces disturbed at intervals of 5, 10, 15 and 25 days for the same period.

7. No correlation existed between the number of root primordia of different varieties and the development of the shoots from the buds, which does not preclude, however, a correlation between development of shoot ("stand of cane") and the number of root primordia for a given variety.

8. Shoot roots developed from the root primordia of the bud and pushed out between the bud scales as early as 5 days after the seed pieces were planted.

9. For the varieties studied the number of shoot roots developing on shoots from seed pieces undisturbed for 50 days *exceeded* the average of the number developing on shoots from seed pieces disturbed at intervals of 5, 10, 15 and 25 days. This is in contrast with the data for the seed-piece roots for, without exception for the same varieties, the percentage of seed-piece roots developing on seed pieces undisturbed for 50 days *was less* than the average of those developing on seed pieces disturbed at intervals of 5, 10, 15 and 25 days.

10. These facts may help interpret the significance of various types of root injury and may have a practical application to the practice of off-barring and subsoiling. The "pruning" of the seed-piece roots stimulated into development root primordia of the seed pieces which under normal conditions would have been held in reserve. The "pruning" of the shoot roots resulted in fewer roots being developed from the shoots.

Relative Resistance and Susceptibility of Hawaiian and Introduced Cane Varieties to Eye Spot and Brown Stripe Diseases

By C. C. Barnum

Part I

Varieties in Relation to Eye Spot Disease

This paper presents all the data that have become available on the subject of inherent eye spot resistance, to the present date. A paper on "Field Observations on the Degree of Resistance and Susceptibility of Seedlings to Eye Spot," by Martin, which appeared in the *Planters' Record*, Vol. XXXII, No. 3, July, 1928, covered only the observations made by himself on canes then growing at Waialua Agricultural Company, Ltd., under eye spot conditions. In this paper, Martin suggested and adopted the plan of using an index sign to indicate the relative resistance or susceptibility to eye spot disease of cane under test.

In the present paper, the observations of all observers are taken into account and the index sign here given is a composite of all records available for each particular cane under observation. The number of observations considered for each seedling is recorded in each instance and the average index sign is determined from a careful weighing of all the recorded observations. Resistance to eye spot disease is indicated by the plus sign, +; extreme resistance by the use of two plus signs, + +; equal susceptibility with that of H 109, as a standard in all cases, is indicated with the equality sign, =; while greater susceptibility to the disease than is exhibited by adjacent lines of similar-aged H 109 cane, is indicated by one or more minus signs, —, — —. Where only one observation for a single variety is recorded too much reliance must not be placed on the index sign here recorded. The canes which have been under field test for agricultural qualities over a relatively long period of time have a larger number of observations recorded herewith than have the more recently developed or introduced canes.

Observations have been made on canes in eye spot areas on both Oahu and Kauai, as well as a few observations on Maui and Hawaii. The observations of R. Bryan, H. K. Stender, R. H. McLennan, J. P. Langley, J. A. Verret, C. G. Lennox, A. J. Mangelsdorf, R. Conant, G. F. Fisher, J. P. Martin, and the writer have all been condensed to form this listing of the canes.

The canes have been grouped in order of their importance and of their propagation; the miscellaneous plantation-propagated canes have been arranged in an alphabetical sequence. The main groups appear in the following sequence:

1. Introduced canes.
2. Standard canes.
3. Alphabet varieties, Oahu propagation 1916-1920.
4. H varieties; H 146 to H 3001.

5. 1917 O. P., 20-S, 1924 O. P. varieties.
6. Manoa varieties, beginning with 1922 propagation.
7. H 5900 varieties.
8. H 7000, H 8100 and H 8600 varieties.
9. H 8900 varieties.
10. H 9800 and H 9900 varieties.
11. U. H. and U. D. varieties.
12. 25-C varieties.
13. 26-C varieties.
14. 27-C varieties.
15. 25-Q varieties.
16. Ewa varieties.
17. Waialua varieties.
18. Wailuku varieties.
19. Miscellaneous varieties.

From time to time observations have been made of the occurrence of mosaic disease on the canes under observation. In this report all varieties on which definite cases of mosaic have been observed are identified by means of an asterisk which precedes the name of the listed variety.

The position of the ×, opposite each variety under either Group I, II, III, or IV, in one of the four columns on the right-hand side of the table, designates the value of the cane variety in relation to eye spot disease. Only those canes for which an × appears in either Group 1 or II are sufficiently resistant for propagation in eye spot areas. Those canes falling in Group III or IV are entirely too susceptible for planting in eye spot areas.

No consideration has been given in this paper to the agricultural qualities of any of the canes listed. The list of cane varieties in relation to eye spot disease is presented in the following table:

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
1. Introduced Canes:						
P. O. J. 36	+	11		×		
" 36M	+	2		×		
" 213	++	10	×			
" 228	+	4		×		
" 234	++	7	×			
" 826	+	4		×		
" 979	++	10		×		
" 2221	+	2		×		
" 2379	+	4		×		
" 2714	+	5		×		
" 2725	+	2		×		
" 2727	+	5		×		
S. W. 3	=	3			×	
D. I. 52	+	5		×		

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
2. Standard Canes:						
D 1135	+	3		×		
Yellow Caledonia	++	5	×			
Yellow Tip	+	5		×		
Uba	+	1		×		
Striped Mexican	+	2		×		
Badila	++	2	×			
3. Alphabet Varieties:						
AA3	=	2			×	
AA4	—	1				×
AA5	——	2				×
AA6	++	2	×			
AA7	+	2		×		
ABA	—	2				×
ABB	=	2			×	
ABC	=	2			×	
ABD	+	2		×		
ABE	=	2			×	
ABF	+	1		×		
ABG	+	1		×		
ABH	+	2		×		
ABI	=	2			×	
ABJ	=	2			×	
ABK	=	1			×	
ABL	—	1				×
ABM	—	1				×
ABN	—	1				×
ABO	—	2				×
ABP	—	1				×
PMB	+	1		×		
4. H Varieties; H 146 to H 3001:						
H 146	+	1		×		
H 333	——	1				×
H 389	+	1		×		
H 411	——	1				×
H 427	——	1				×
H 455	+	1		×		
-H 456	+	11		×		
H 460	+	1		×		
H 463	+	1		×		
H 471	—	3				×
H 3001	=	3			+	
5. 1917 O. P., 20-S, and 1924 O. P. Varieties:						
1917 O. P. 86	—	1				×
1917 O. P. 299	++	1	×			
1917 O. P. 384	=	1			×	

* Asterisk preceding the name of any variety indicates the observation of mosaic disease on such canes.

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
1917 O. P. 389	−	1				×
1917 O. P. 395	++	1	×			
1917 O. P. 710	=	1			×	
20-S-16	++	4	×			
20-S-17	++	1	×			
20-S-18	+	2		×		
20-S-19	=	4			×	
1924 O. P. 83	=	2			×	
1924 H 3	+	1		×		
1924 H 129	+	1		×		
1924 L 4	+	1		×		
6. Manoa Varieties:						
Manoa 36	=	2			×	
" 127	+	2		×		
" 160	+	1		×		
" 198	++	1	×			
" 213	=	1			×	
" 300	+	1		×		
" 301	+	3		×		
" 302	++	1	×			
" 303	++	2	×			
" 304	++	2	×			
" 305	++	1	×			
" 306	+	1		×		
" 309	+	1		×		
" 311	+	1		×		
7. H 5900 Varieties:						
H 5908	− −	2				×
H 5909	++	9	×			
H 5919	++	5	×			
H 5922	=	1			×	
H 5923	+	1		×		
H 5940	−	1				×
H 5946	+	3		×		
H 5949	+	3		×		
H 5965	+	1		×		
H 5972	=	2			×	
H 5974	+	1		×		
H 5978	+	2		×		
H 5986	=	3			×	
8. H 7000, H 8100 and H 8600 Varieties:						
H 7101	+	3		×		
H 7102	−	3				×
H 76719	+	5		×		
H 7860	=	2			×	
H 7878	=	2			×	

	Index Sign	Number of Observations	Resistant		Susceptible	
			Group I Highly Resistant	Group II Moderately Resistant	Group III Equal to H 109	Group IV Highly Susceptible
H 8136	— —	3				×
H 8139	— —	4				× ×
H 8158	—	3				× ×
H 81360	+	10		×		
H 86143	+ +	4	×			
H 86374	=	3			×	
H 86441	—	4				×
H 86465	+ +	6	×			
H 86472	+ +	6	×			
H 86484	+	10		×		
H 86485	+	1		×		
H 8900 Varieties:						
H 8901	=	3			×	
H 8906	=	4			×	
H 8907	+ +	2	×			
H 8911	=	2			×	
H 8918	=	2			×	
H 8919	=	2			×	
H 8920	+	1		+		
H 8922	=	2			×	
H 8924	—	1				×
H 8929	+	1		×		
H 8933	=	2			×	
H 8935	—	3				×
H 8938	—	1				×
H 8939	+ +	1	×			
H 8940	=	2			×	
H 8942	+	6		×		
H 8945	+	2		×		
H 8946	—	1				×
H 8947	=	2			×	
H 8948	+	2		×		
H 8949	— —	2				×
H 8952	+ +	9	×			
H 8954	=	5			×	
H 8956	—	1				×
H 8958	=	5			×	
H 8961	+ +	8	×			
H 8965	+	16		×		
H 8968	—	1				×
H 8969	+	7		×		
H 8973	—	2				×
H 8976	=	1			×	
H 8978	=	4			×	
H 8982	=	1			×	
H 8983	—	3				×
H 8984	=	3			×	

	Index Sign	Number of Observations	Resistant: Group I Highly Res	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H	Susceptible: Group IV Highly Susceptible
H 8988	+	8		×		
H 8992	−−	2				×
H 8993	++	8	×			
H 8994	++	14	×			
H 8998	+	3		×		
H 89102	+	8		×		
H 89291	−−	5				×
H 89296	−	2				×
H 89321	++	2	×			
10. H 9800 and H 9900 Varieties:						
H 9801	+	1		×		
H 9802	+	1		×		
H 9803	+	1		×		
H 9804	+	1		×		
H 9805	+	1		×		
H 9806	+	4		×		
H 9807	+	1		×		
H 9808	++	1	×			
H 9809	+	2		×		
H 9810	+	2		×		
H 9811	++	4	×			
H 9872	+	3		×		
H 9813	+	1		×		
H 9904	=	2			×	
H 9910	+	1		×		
H 9913	+	1		×		
H 9923	+	2		×		
H 9924	+	1		×		
H 9929	+	1		×		
11. U. H. and U. D. Varieties:						
U. H. 1	++	3	×			
U. H. 2	++	1	×			
U. H. 3	++	1	×			
U. H. 4	++	1	×			
U. D. 1	+	11		×		
U. D. 4	++	1	×			
U. D. 6	++	1	×			
U. D. 7	++	1	×			
U. D. 23	++	1	×			
U. D. 35	++	1	×			
U. D. 39	++	2	×			
U. D. 42	++	1	×			
U. D. 58	++	3	×			
U. D. 62	++	3	×			
U. D. 65	+	3		×		

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to II 109	Susceptible: Group IV Highly Susceptible
U. D. 66	++	1	×			
U. D. 75	++	3	×			
U. D. 79	++	1	×			
U. D. 88	++	1	×			
U. D. 92	++	1	×			
U. D. 100	++	2	×			
U. D. 104	++	1	×			
U. D. 106	++	1	×			
U. D. 110	++	1	×			
25-C Varieties:						
25-C-1	+	5		×		
25-C-2	+	3		×		
25-C-3	+	3		×		
* 25-C-4	+	8		×		
25-C-5	=	3			×	
25-C-6	+	3		×		
25-C-7	+	7		×		
25-C-8	+	4		×		
25-C-9	—	5				×
25-C-10	— —	4				×
25-C-11	=	3			×	
25-C-12	+	3		×		
25-C-13	—	3				×
* 25-C-14	+	3		×		
25-C-15	+	8		×		
25-C-16	+	7		×		
25-C-17	—	4				×
25-C-18	— —	3				×
25-C-19	—	5				×
25-C-20	— —	4				×
25-C-21	=	4			×	
25-C-22	=	3			×	
25-C-24	+	8		×		
25-C-25	=	2			×	
25-C-26	— —	3				×
25-C-27	— —	3				×
* 25-C-28	=	4			×	
25-C-29	—	2				×
25-C-30	+	3		×		
25-C-31	++	4	×			
25-C-32	+	3		×		
25-C-33	—	2				×
25-C-34	++	6	×			
25-C-35	=	3			×	
25-C-36	—	2				×
25-C-37	+	2		×		
25-C-38	+	4		×		

	Index Sign	Number of Observations	Resistant		Susceptible	
			Group I Highly Resistant	Group II Moderately Resistant	Group III Equal to H 109	Group IV Highly Susceptible
25-C-39	+	2		×		
25-C-40	=	2			×	
25-C-41	+	3		×		
25-C-42	+	3		×		
25-C-43	—	2				×
25-C-44	—	2				×
25-C-45	— —	2				×
25-C-46	+	3		×		
25-C-47	=	2			×	
13. 26-C Varieties:						
26-C-48	++	4	×			
26-C-52	=	5			×	
26-C-53	=	1			×	
26-C-55	—	2				×
26-C-58	+	1		×		
26-C-61	+	2		×		
26-C-63	+	2		×		
26-C-71	+	5		×		
26-C-80	+	1		×		
26-C-95	— —	1				×
26-C-110	=	1			×	
26-C-112	+	2		×		
26-C-113	++	3	×			
26-C-116	=	3			×	
26-C-118	+	2		×		
26-C-122	++	2	×			
26-C-137	—	1				×
26-C-141	+	1		×		
26-C-143	=	1			×	
26-C-144	—	1				×
26-C-148	++	4	×			
26-C-149	=	1			×	
26-C-152	+	1		×		
26-C-157	— —	1				×
26-C-163	=	3			×	
26-C-165	+	1		×		
26-C-169	=	1			×	
26-C-176	=	1			×	
26-C-177	=	2			×	
26-C-182	+	3		×		
26-C-188	+	2		×		
26-C-189	+	4		×		
26-C-191	=	1			×	
26-C-193	=	1			×	
26-C-194	—	2				×
26-C-196	=	1			×	
26-C-199	—	1				×

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to II 109	Susceptible: Group IV Highly Susceptible
26-C-204	−−	2				×
26-C-211	++	1	×			
26-C-213	−	1				×
26-C-216	−	3				×
26-C-219	−	2				×
26-C-222	−	1				×
26-C-226	−−	1				×
26-C-228	−−	1				×
26-C-235	−−	1				×
26-C-237	−−	1				×
26-C-240	−−	1				×
26-C-241	−	2				×
26-C-245	=	2			×	
26-C-249	=	2			×	
26-C-250	+	3		×		
26-C-254	+	1		×		
26-C-256	++	1	×			
26-C-259	=	1			×	
26-C-261	−	2				×
26-C-263	++	2	×			
26-C-264	=	1			×	
26-C-266	++	1	×			
26-C-267	++	1	×			
26-C-268	++	4	×			
26-C-270	+	1		×		
26-C-274	+	2		×		
26-C-277	=	1			×	
26-C-292	−−	1				×
14. 27-C Varieties:						
27-C-289	++	1	×			
27-C-340	++	1	×			
27-C-346	+	1		×		
27-C-372	++	1	×			
27-C-376	+	1		×		
27-C-378	++	1	×			
27-C-445	+	2		×		
27-C-452	+	1		×		
27-C-453	+	1		×		
27-C-483	++	1	×			
27-C-485	+	1		×		
27-C-548	+	1		×		
27-C-549	+	1		×		
27-C-556	+	1		×		
27-C-557	+	1		×		
15. 25-Q Varieties:						
25-Q-1	+	1		×		
25-Q-11	++	1	×			

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
25-Q-18	++	1	×			
25-Q-25	+	1		×		
25-Q-70	++	1	×			
25-Q-73	++	1	×			
25-Q-79	++	1	×			
25-Q-110	++	1	×			
25-Q-119	+	1		×		
25-Q 126	+	1		×		
25-Q-156	++	1	×			
25-Q-214	++	1	×			
25-Q 224	++	1	×			
16. Ewa Varieties:						
Ewa 177	+	2		×		
" 199	——	4				×
" 325	+	1		×		
" 371	+	1		×		
" 533	++	4	×			
" 555	+	3		×		
" 566	++	1	×			
" 569	++	3	×			
" 570	++	4	×			
" 580	——	1				×
" 607	—	3				×
" 608	+	3		×		
" 609	+	3		×		
" 610	=	3			×	
" 611	+	4		×		
" 612	=	3			×	
" 613	=	3			×	
" 614	=	3			×	
" 615	=	3			×	
" 616	++	4	×			
" 617	=	3			×	
" 618	+	3		×		
" 619	+	3		×		
" 620	++	3	×			
" 621	+	3		×		
" 622	=	3			×	
" 623	—	3				×
" 624	—	3				×
" 625	——	4				×
" 626	=	4			×	
" 627	=	3			×	
" 628	+	3		×		
" 629	——	3				×
" 630	—	3				×
" 631	—	3				×

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
Ewa 639	=	1			×	
" 800	=	5			×	
" 801	+	5		×		
" 802	=	3			×	
" 803	—	3				×
" 804	+	3		×		
17. Waialua Varieties:						
Waialua 1	++	5	×			
" 2	+	3		×		
" 3	++	3	×			
" 4	+	5		×		
" 5	=	2			×	
" 6	++	3	×			
" 7	=	2			×	
" 8	+	5		×		
" 9	++	3	×			
" 10	+	1		×		
" 11	+	1		×		
" 13	++	1	×			
" 14	++	1	×			
" 15	++	1	×			
" 16	++	1	×			
" 17	++	1	×			
" 18	++	1	×			
" 19	=	1			×	
" 20	+	1		×		
" 21	++	1	×			
" 22	++	1	×			
" 23	+	1		×		
" 24	=	1			×	
" 25	++	1	×			
" 26	=	1			×	
" 27	+	1		×		
" 28	++	1	×			
" 29	+	1		×		
" 30	+	1		×		
" 31	++	1	×			
" 32	+	1		×		
" 33	+	1		×		
" 34	+	1		×		
" 35	+	1		×		
" 36	++	1	×			
" 37	+	1		×		
" 38	+	1		×		
" 39	+	1		×		
" 40	+	1		×		
" 41	+	1		×		

	Index Sign	Number of Observatior	Resistant: Group I Highly Res	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H	Susceptible: Group IV Highly Susceptible
Waialua 42	+	1		×		
" 43	+	1		×		
" 44	++	1	×			
" 45	+	1		×		
" 46	+	1		×		
" 47	+	1		×		
" 48	=	1			×	
" 49	+	1		×		
" 50	+	1		×		
" 51	++	1	×			
" 52	++	1	×			
" 53	+	1		×		
" 54	=	1			×	
" 55	=	1			×	
" 56	=	1			×	
" 57	+	1		×		
" 58	+	1		×		
" 59	+	1		×		
" 60	+	1		×		
" 61	+	1		×		
" 62	+	1		×		
" 63	=	1			×	
" 64	+	1		×		
" 65	+	1		×		
" 66	+	1		×		
" 67	+	1		×		
" 68	+	1		×		
" 69	—	1				×
" 70	+	1		×		
" 71	+	1		×		
" 72	++	1	×			
" 73	+	1		×		
" 74	+	1		×		
" 75	+	1		×		
" 76	+	1		×		
" 77	=	1			×	
" 78	+	1		×		
" 79	+	1		×		
" 80	+	1		×		
" 81	+	1		×		
" 82	+	1		×		
" 83	—	1				×
" 84	+	1		×		
" 85	+	1		×		
" 86	+	1		×		
" 87	+	1		×		
" 88	=	1			×	
" 89	+	1		×		

	Index Sig	Number o Observatio	Resistant: Group I Highly Re	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to]	Susceptible: Group IV Highly Susceptibl
Waialua 90	+	1		×		
" 91	+	1		×		
" 92	+	1		×		
" 93	+	1		×		
" 94	+	1		×		
" 95	+	1		×		
" 96	+	1		×		
" 97	+	1		×		
" 98	+	1		×		
" 99	+	1		×		
" 100	+	1		×		
" 101	+	1		×		
" 102	+	1		×		
" 103	=	1			×	
" 105	+	1		×		
" 106	+	1		×		
" 107	+	1		×		
" 108	+	1		×		
" 110	+	1		×		
" 111	+	1		×		
" 112	+	1		×		
" 115	+	1		×		
" 116	+	1		×		
" 117	=	1			×	
" 119	+	1		×		
" 120	+	1		×		
" 121	+	1		×		
" 122	+	1		×		
" 123	+	1		×		
" 124	+	1		×		
" 125	+	1		×		
" 126	+	1		×		
" 127	+	1		×		
" 128	+	1		×		
" 129	+	1		×		
" 130	+	1		×		
" 131	+	1		×		
" 132	+	1		×		
18. Wailuku Varieties:						
* Wailuku 1	+	7		×		
" 2	+	6		×		
" 3	+	2		×		
* " 4	=	6			×	
" 5	=	2			×	
" 6	=	2			×	
" 8	—	1				×
" 9	=	1			×	

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
Wailuku 10	+	4		×		
" 11	+	11		×		
" 12	+	2		×		
" 13	=	2			×	
" 17	—	1				×
" 29	=	1			×	
" 30	+	1		×		
" 47	+	1		×		
" 48	+	2		×		
" 51	+	7		×		
" 53	+	1		×		
" 63	+	1		×		
" 66	++	1	×			
" 73	++	3	×			
" 60701	=	1			×	
19. Miscellaneous Varieties:						
Grove Farm 84	=	3			×	
Honokaa 1	+	4		×		
Hononu 5	+	1		×		
" 7	=	1			×	
" 9	+	2		×		
" 16	+	1		×		
" 27	+	1		×		
Kekaha 3	=	1			×	
" 25-3	++	1	×			
" 25-8	=	1			×	
" 25-9	—	1				×
" 26-12	—	1				×
" 26-13	=	1			×	
" 456	+	5		×		
Kilauea 2	+	2		×		
Kohala 73	+	6		×		
" 105	+	2		×		
* " 107	+	3		×		
" 115	++	2	×			
* " 202	+	10		×		
Koloa X2	+	3		×		
" X8	+	1		×		
Lihue Plantation Varieties:						
L. P. 9	+	1		×		
L. P. 14	++	1	×			
L. P. 25	=	1			×	
L. P. 27	+	1		×		
L. P. 34	+	1		×		

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
L. P. 36	—	1				×
L. P. 38	+	1		×		
L. P. 40	+	1		×		
L. P. 49	—	1				×
L. P. 60	+	1		×		
L. P. 65	+	1		×		
L. P. 91	+	1		×		
Makee Varieties:						
Kealia 1 (K. M. 1)	=	2			×	
K. M. 1-5	—	1				×
K. M. 1-7	—	1				×
K. M. 1-13	—	1				×
K. M. 2-1	—	1				×
K. M. 2-3	—	1				×
K. M. 2-8	=	1			×	
K. M. 2-10	+	1		×		
K. M. 4-3	=	1			×	
K. M. 4-10	—	1				×
Makaweli Varieties:						
Mak. 1	=	1			×	
" 3	+	5		×		
" 309		0				
" 476	=	1			×	
McBryde Varieties:						
McB. "H"	—	2				×
" 1	—	2				×
" 3	=	2			×	
" 4	+	2		×		
" 5	—	4				×
" 6	+	2		×		
" 7	=	1			×	
" 8	+	2		×		
Waimanalo Varieties:						
Nalo 13	=	2			×	
" 31	+	5		×		
" 44	+	5		×		
Onomea H 109	=	1			×	
Onomea 2	+	1		×		
Paia F	+	4		×		
" D	=	1			×	
" 71	—	2				×
" 75	=	1			×	
" 150	=	3			×	

	Index Sign	Number of Observations	Resistant: Group I Highly Resistant	Resistant: Group II Moderately Resistant	Susceptible: Group III Equal to H 109	Susceptible: Group IV Highly Susceptible
Paia 163	—	2				×
" 180	+	5		×		
" 186	+	5		×		
Paauhau 1	+	1		×		
Puunene 230	++	1	×			
Waipio 7	+	4		×		
" 8	+	4		×		
" 152	+	1		×		
Waipahu 30	++	1	×			
" 31	+	1		×		
" 35	+	1		×		
" 36	++	1	×			
" 51	++	1	×			
" 81	++	1	×			
" 89	++	1	×			
" 97	+	2		×		
" 129	+	2		×		
" 137	+	1		×		
" 152	+	1		×		

Part II

Cane Varieties in Relation to Brown Stripe Disease

The earliest extensive publication on brown stripe is the work of Faris (1) in which he differentiates between three *Helminthosporium* leaf diseases of sugar cane in Cuba. In this paper he points out the differences between eye spot and brown stripe diseases. Drechsler (2) reported at the meeting of the American Phytopathological Society at Nashville, Tennessee, the occurrence of brown stripe in Cuba, Georgia and Florida and provisionally named the causal organism, *Helminthosporium stenospilum* n. sp. Martin and Agee (3) in October, 1928, pointed out the resemblance of the leaf disease appearing at Waialua Agricultural Company, to the disease designated by Faris and Drechsler as brown stripe disease of sugar cane. Cultural work on the organism has been conducted by Martin, and the organism isolated from typical brown stripe lesions on H 109 leaves collected at Waialua agreed with the description of *H. stenospilum* Drechsler.

It has been observed that many of those varieties which have shown definite resistance to eye spot disease have suffered considerably from attacks of brown stripe disease. There is some evidence to show that field conditions which make for poor cane growth favor brown stripe infection. Germination of the spores

and subsequent leaf infection is, however, dependent upon the presence of adequate moisture on the leaf surfaces. As Faris (1) points out in his work, "Brown stripe becomes destructive during periods of dry weather when the vitality of the cane is lowered . . ." The most severe outbreaks of brown stripe disease in Hawaii, have usually occurred on the less fertile fields and have been most noticeable during the drier summer and fall months. The severity of brown stripe disease on H 109 is being recognized in several areas. Further investigations of brown stripe disease are under way at this time.

The relative susceptibility of certain varieties to brown stripe disease has been observed and noted from time to time by members of the Station staff during the past year. The following list of canes has been arranged in much the same sequence as has been used in the listing of canes in relation to their resistance and susceptibility to eye spot disease. The list does not include as many canes as are tabulated in Part I of this paper, and includes only those canes on which several observations have been made. The list follows:

INTRODUCED AND STANDARD CANES

P. O. J. 36	Slightly affected
P. O. J. 234	Severely affected
P. O. J. 826	" "
P. O. J. 979	" "
P. O. J. 2221	" "
P. O. J. 2714	Slightly affected
P. O. J. 2878	Severely affected
S. W. 3	" "
H 109	Moderately affected
D 1135	" "
Badila	Severely affected
Yellow Caledonia	" "
Yellow Tip	Slightly affected
Striped Tip	" "
Uba	Moderately affected

HAWAIIAN VARIETIES

H 146	Severely affected
H 5909	Slightly affected
H 5919	Severely affected
20-S-18	" "
20-S-19	" "
H 81360	" "
H 86374	" "
H 8952	" "
H 8954	" "
H 8961	Slightly affected
H 8965	Moderately affected
H 8988	Severely affected
H 8994	Slightly affected
H 9806	" "

Ewa 371	Severely affected
" 628	" "
Kohala 107	Slightly affected
" 202	" "
Manoa 198	" "
" 300	" "
Makaweli 3	" "
Paia F	" "
" 150	" "
" 186	Severely affected
Waialua 1	" "
" 4	Slightly affected
" 8	" "
Wailuku 11	Severely affected
" 12	Slightly affected
Waipahu 129	Severely affected
25-C-24	Slightly affected
25-C-31	Severely affected
27-C-306	" "
27-C-340	" "
27-C-372	" "
27-C-375	" "
27-C-391	" "
27-C-536	" "

LITERATURE CITED

(1) Faris, James A. 1928. Three Helminthosporium Diseases of Sugar Cane. Phytopathology, Vol. 18, pp. 753-774.

(2) Drechsler, Chas. 1928. A Species of Helminthosporium Distinct from Helminthosporium sacchari, Causing Brown Stripe of Sugar Cane. Phytopathology, Vol. 18, pp. 135-136.

(3) Director's Monthly Letter, October, 1928. Experiment Station, H. S. P. A.

Sugar Prices

96° Centrifugals for the Period

September 19, 1929, to December 13, 1929.

Date		Per Pound	Per Ton	Remarks
Sept.	19, 1929	3.96¢	$79.20	Porto Ricos.
"	20	3.96	79.20	Porto Ricos.
"	24	4.05	81.00	Porto Ricos, 4.02; Cubas, 4.08.
"	25	4.08	81.60	Cubas.
Oct.	8	4.05	81.00	Cubas.
"	21	4.02	80.40	Cubas.
"	28	3.89	77.80	Cubas.
"	29	3.83	76.60	Cubas.
Nov.	1	3.74	74.80	Philippines.
"	7	3.74	74.80	Philippines, 3.71; Cubas, 3.77.
"	12	3.71	74.20	Cubas.
"	16	3.77	75.40	Cubas.
"	19	3.71	74.20	Cubas.
"	22	3.77	75.40	Porto Ricos.
"	25	3.725	74.50	Cubas, 3.74, 3.71.
"	26	3.68	73.60	Cubas.
Dec.	2	3.74	74.80	Cubas.
"	3	3.71	74.20	Cubas.
"	10	3.74	74.80	Philippines.
"	11	3.77	75.40	Porto Ricos.
"	13	3.83	76.60	Philippines.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXIV. APRIL, 1930 Number 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Plot Replications in Field Experiments

The errors to which field experiments are subject are classified into various groups according to the cause of the error. Some errors tend to be compensating, others are not The influence of plot replications in reducing the effect of errors of different sorts on yield accuracy is dealt with mathematically from the standpoint of "probable error." It is shown that there is much to be gained in accuracy by increasing within certain limits the number of plots of each treatment, provided that the nature of the soil to which the field trial is thus extended, does not, of itself, induce greater errors than the replication of plots tends to cover.

Lysimeter Experiments and Base Exchange.

Chemical and physical reactions in base replacement and the results of corrective treatment are frequently confined to considerations involving surface soil phenomena. In this issue will be found a discussion of the drainage products of replacement reactions. The functions of nitrogenous fertilizers in relation to soil acidity are also discussed.

Sugar Cane in Relation to Drought Resistance

The osmotic concentration of the tissue fluids of seven sugar cane varieties was measured by determining the freezing point depression, i. e., the difference between the freezing point of the tissue fluid and that of pure water. From the results of the investigations there appears to be a correlation between the osmotic concentration and drought resistance. Uba cane is no doubt the most drought-resistant variety in Hawaii and it has the greatest freezing point depression and highest osmotic concentration of the varieties studied. Lahaina cane, which has a low freezing point depression and osmotic concentration, is without question very sensitive to drought.

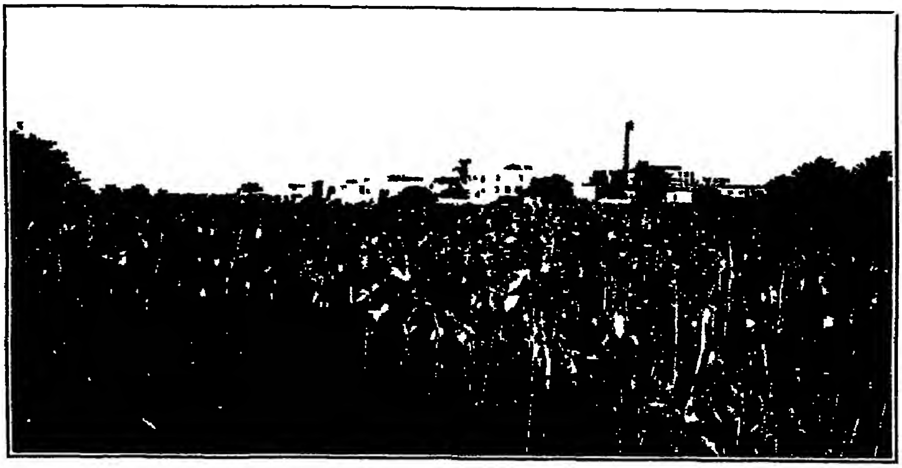
Influence of Irrigation Water on Island Soils:

On our plantations which are irrigated with artesian water, some fields have been reduced in fertility by salt accumulations and lowered permeability. Such soil conditions are known to follow abnormal changes in the composition of the soil solution and of certain silicate components of the clay known as zeolites. We have made a study of fields of an irrigated plantation, paying special attention to these factors, using as a basis for the investigation new developments in soil science both on the mainland and in Europe. The results of our investigation have shown the cause of low permeability of some irrigated fields and yielded methods of avoiding further recurrence of such conditions and of improving the texture of fields already reduced in permeability. A comparative study of irrigation waters with many mainland waters gave information which greatly aided in the interpretation of field conditions under study on Oahu. Mainland investigators have shown that soil permeability may be efficiently controlled through a knowledge of the composition of the irrigation water and of the soil zeolites. Our studies tend to confirm this.

Annual Synopsis of Mill Data:

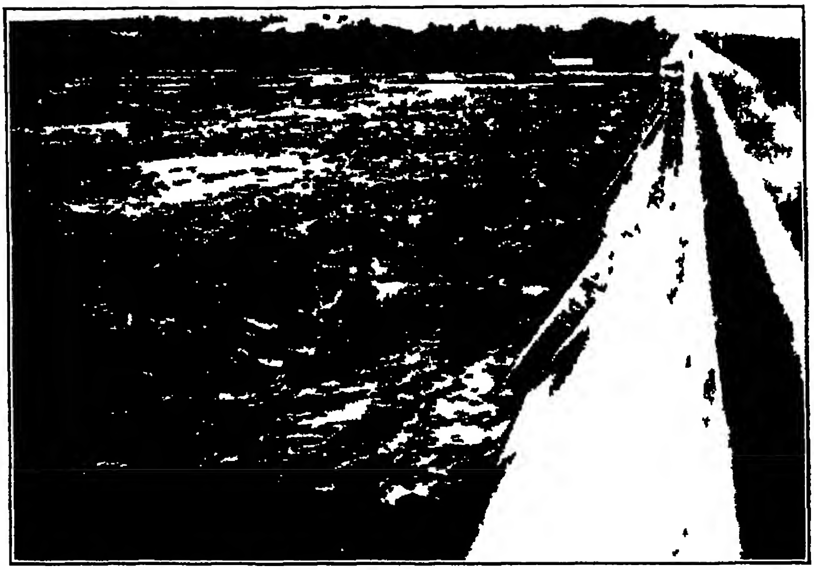
The 1929 Annual Synopsis of Mill Data is included in this issue. In addition to the usual tabulations and discussion of technical results, capacities of factory equipment are presented in this Synopsis. The 1929 Synopsis has been published separately as Circular 54.

Egyptian Views

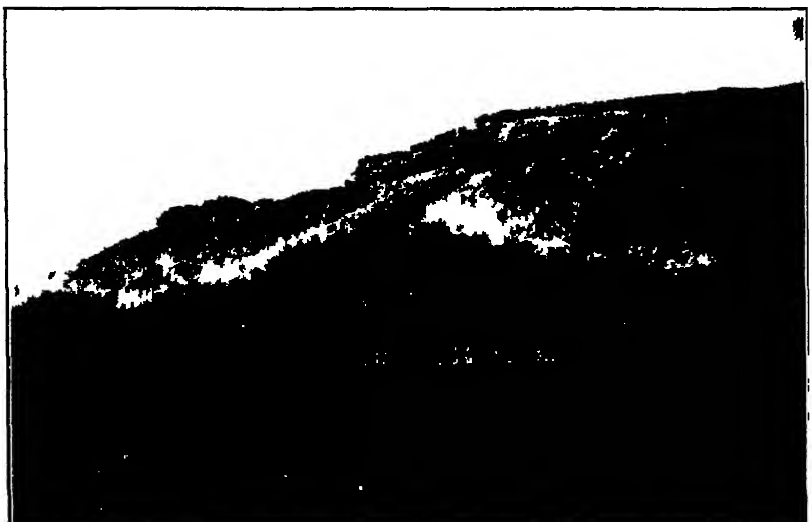


The sugar refinery at Hawamdieh, on the banks of the Nile, that handles the output of six factories. The factories and refinery being under the same ownership, the raw sugar has a high polarization, much of it over 99, thus enabling it to enter the refining process without affination. The crop in the foreground is Milo maize.

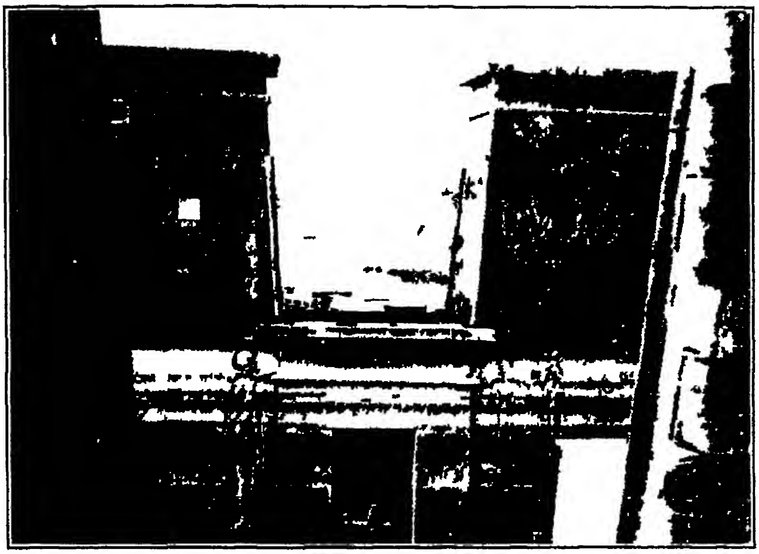
The principal cane varieties of Egypt are the P.O.J. canes of Java. On the right is P.O.J. 105, on the left P.O.J. 979, a cane which is apparently immune to the streak disease that abounds in all African cane districts.



The great dam of Assuan which causes the flood waters of the Nile to be impounded to a distance of 175 miles to the south thereby enabling the flow of the river to be regulated in the dry season so that irrigation may be maintained



Near Assuan the valley of the Nile dwindles to nothing and the cliffs of the desert overhang the river



The Assuan reservoir seen through the pylons of Philae located on an island of the river. The high water line can be seen in the distance and in the foreground and on the temple itself. When the dam is increased in height by 18 feet as now planned Philae will be completely submerged in the winter season.

Nile river boats

A field of sugar cane showing irrigation ditch

P O J 105 The growth in front of these field guards is a wild grass

Relics of Egyptian architecture as seen through the date palms

Traffic on an Egyptian roadway

Garden about a plantation guest house at Nag Hamadi

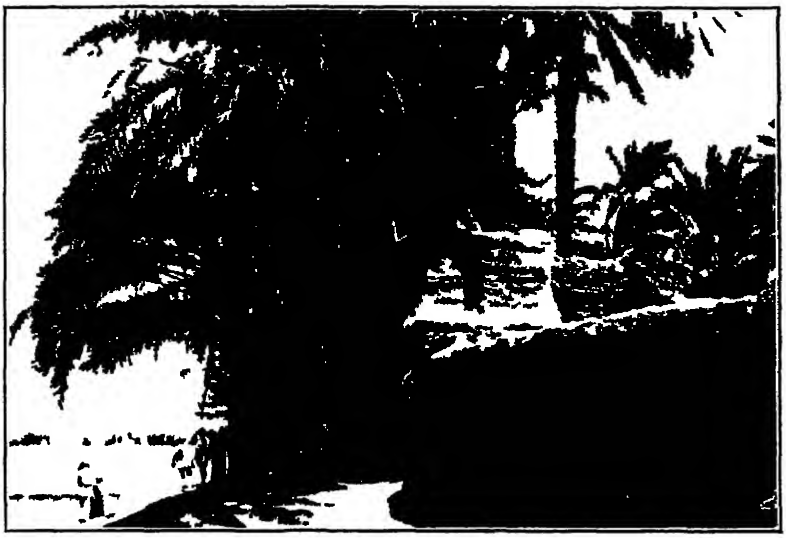
Saccharum spontaneum growing wild near Cairo

Sugar cane variety plots

Cotton, the principal crop of Egypt, has been the subject of much research on the part of the Royal Agricultural Society

Arabian stallion from the stables of the Royal Agricultural Society

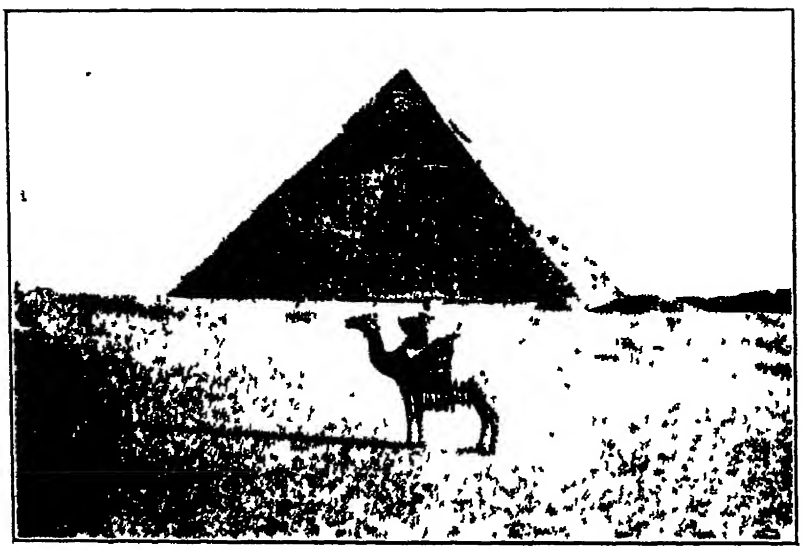
A primitive means of lifting water still common in Egypt, although the modern pumping plant likewise exists



Mud walls of a native village

The temple of Karnak

Typical view of a cane field.



P. O. J. 36

P. O. J. 36 is being widely planted on Hawaii and Kauai, especially in areas where the rainfall is ample.

The total area planted in 1927 on the four islands amounted to only 103 acres. The 1929 plantings amounted to 2922 acres. Through the cooperation of the plantations, the plantings to be made in 1930 have been forecasted. The island of Hawaii leads with 2572 acres in prospect, followed by Kauai with 1382 acres. These data are presented in the following table:

	Acres Planted 1927	Acres Planted 1928	Acres Planted 1929	Acres to be Planted 1930
HAWAII:				
Hakalau	....	....	22	200
Hamakua Mill	1	12	5	25
Hawaiian Agr.	....	....	16	130
Hawi Mill	24	60	70	100
Hilo	....	1	9	75
Honokaa	37*	171	187	225
Honomu	....	1	20	200
Hutchinson	10	69	170	500
Kaiwiki	....	....	1	5
Kohala	....	....	5	90
Laupahoehoe	....	....	3	35
Niulii	....	....	4	12
Olaa	....	2	34	325
Onomea	....	6	123	260
Paauhau	11	43	257	300
Pepeekeo	....	....	....	10
Union Mill	....	1	8	80
Waiakea Mill	....	....	....	....
Total	83	366	944	2572
MAUI:				
H. C. & S. Co	....	....	....	....
Kaeleku	....	....	4	20
Maui Agr.	....	....	....	....
Olowalu	....	1	13	....
Pioneer Mill	....	....	....	....
Wailuku	....	....	....	4
Total	0	1	17	24
OAHU:				
Ewa	....	....	....	....
Honolulu Pltn.	....	26	56	25
Kahuku	....	....	2	40
Laie	....	....	5	25
Oahu Sugar Co.	....	....	3	....
Waialua	....	....	....	....
Waianae	....	....	....	....
Waimanalo	....	31	375	250
Total	0	57	441	340
KAUAI:				
Grove Farm	....	11	46	160
Hawaiian Sugar Co.	....	....	....	....
Kekaha	....	5	....	25
Kilauea	....	9	155	100
Kipu	15	70	77	140
Koloa	....	102	236	100
Lihue	5	102	628	339
Makee	....	84	274	453
McBryde	....	4	104	65
Waimea	....	....	....	....
Total	20	387	1520	1382
Grand Total	103	811	2922	4318

* Planted by Pacific Sugar Mill.

Replication of Plot Treatments in Field Experiments

By Ralph J Borden

We have heard considerable, during recent discussions of experimental plot technique, concerning the matter of replication of treatments in our layouts for field experiments. Our attention has frequently been called to the wide range in yields which have been obtained from even those experimental plots which have had presumably identical treatment, and most of us have learned to appreciate and take cognizance of the experimental error which is included in the results of our field tests. We have come to realize that a small experimental or probable error attached to our results is synonymous with their reliability and gives us greater confidence that we can produce similar results again. This feeling of confidence is particularly evidenced when many replications of any particular plot treatment give us yields that are accompanied by low probable errors.

W. P Alexander has pointed out that there are certain unavoidable as well as controllable errors which create varying conditions in our test plots, and he suggests consideration of measures of proper technique and control. Messrs. Greene and Wolters* have briefly outlined some of the errors in our experimental plots which may affect results. Since the idea of plot replication is so closely tied up with this question of errors, an analysis of these errors is desirable.

Errors of Location: (1) Perhaps the most variable factor that we have to deal with in our test plot work, is the extreme soil heterogeneity which we encounter in our cane fields. This variation in the soil conditions may take the form of a difference in the inherent fertility, in drainage, in the water-holding capacity, in depth, exposure, or in former treatment, and it is not always evident to the eye when we "select a uniform piece of land for the experimental area." Nevertheless the difference is there, and must be considered as perhaps of major importance when we interpret our experimental results, for it may introduce an error that not only affects the results of one crop, but persists through following crops, and gives us false ideas of confidence.

(2) Plot competition may bring into our results another error which persists throughout the life of the experiment. Naquin† has given us some excellent examples of this fact, and in general, it has been given some consideration in our tests laid out on the unirrigated lands. It still is an error factor which exists in our irrigated plots and as such must have our attention in developing an improved technique for conducting field experiments.

Errors of Preparation and Planting: In any field test, it is essential that we have comparable stands within the individual unit plots which make up the test

* Mimeographed papers submitted to members of the Committee on Experimental Technique of the A. H. S. T. during 1929.
† *Hawaiian Planters' Record*, Vol. XXXIII, p. 421.

area. Differences in plowing, in furrowing out, in width between lines, in cleaning out the lines for planting, in seed used, are apt to result in an uneven stand or growth of cane, which may possibly introduce errors too large to be compensating ones, even though larger plots and many replications are employed in an attempt to distribute the effect of such errors.

Errors During Progress: After a uniform stand has been obtained in the test plots, the many operations that are yet necessary before the crop is mature are quite likely to introduce more errors. Inaccuracies in weighing out fertilizers and unevenness in their application, differences in the amount of water applied to individual plots by irrigation, variations in weed control work or in other cultural operations, as well as attacks of insect pests, disease, and rat damage, all undoubtedly have their effect on the plot yields. These are seldom as large as the errors previously mentioned, and are such that perhaps their effect can be distributed and thereby reduced by replicating the varieties of the experiment.

Errors During Harvest: Harvesting errors are generally due to: (1) the difficulty of an accurate separation of a tangled mass of cane stalks at the edges of the plots, (2) the failure of the cutting gang to cut stalks off uniformly at base and top, (3) inclusion of considerable trash with cane sticks. With sufficient replications of each plot treatment, it is quite possible that because of the large number of individual plants we have in each plot, these errors are of that class which are called compensating and they are not apt to affect one series of plots any more than another.

Errors During Transportation; Errors of Weighing; Errors in Measuring Areas: No matter how careful our experimental technique is in the field, it avails us little unless we can secure accurate weights of our product and express these in comparable and usable terms. Errors which are due to loss of cane sticks in transit from field to scales cannot be called compensating errors. The effect of inaccuracies in weighing and determining net cane weights cannot be eliminated from the plot results; they must therefore be avoided. Errors in measuring areas are avoidable and should have no place in our experimental work.

Relative Importance: From this analysis of the errors that get into our experimental results, it would seem that the variations in soil, the plot competition, and the incomparable stands make up for the greater part of the experimental error which accompanies our field test work. How, then, can we reduce the effect of such errors?

Replication: The literature on experimental technique contains many statements to the effect that replications are extremely valuable in reducing the errors that get into field experiments, and considerable data are available which seem to bear out such statements.

It is rather difficult to accept such statements, without qualifying them. In a general way, there is no question but that errors which get into our experiments during their progress and at harvest time, can be so distributed over a number of plots, that their effect upon the yields from any particular group is negligible. On the other hand, it is very difficult to conceive of replication being of value in reducing that error of location, which is due to plot competition. If an A plot

receiving 75 pounds of nitrogen is replicated adjacent to a C plot that is getting 225 pounds, in our usual series layout with watercourse plots, it is hard to believe that those plants at the ends of the 35 or 40 rows in the A plot will not reach across the watercourse and help themselves to the more abundant nitrogen supply of the C plots, thus introducing an error which cannot be affected by the usual method of replication.

Until such time as we have data to prove that we are justified in correcting the results of our test plots to allow for variations in stand thereon, we can perhaps reduce the effect of this error by using a sufficient number of replications of each treatment and making our plot areas large enough to distribute such inequalities.

It is with that *error of location* which is due to *soil variation* that this question of replication becomes paramount, and fortunately, one of our recently harvested uniformity tests, offers us figures for an intensive study.

The interesting manner in which the probable errors of a series of plots may change as the number of plots is increased, is clearly shown in the Uniformity or Blank Test harvested at Hakalau Plantation in 1929.

	Column I		II		III		IV	
	Plot	T.C.A.	Plot	T.C.A.	Plot	T.C.A.	Plot	T.C.A.
Row A	1	99.3	14	99.6	27	106.2	40	90.2
B	2	98.8	15	77.5	28	94 5	41	82.7
C	3	82.3	16	90.3	29	91.6	42	85.0
D	4	77.8	17	83.6	30	88.5	43	90.7
E	5	79.6	18	82.9	31	88.2	44	91.8
F	6	75.9	19	86.5	32	87.5	45	87.8
G	7	81.1	20	72.7	33	81.1	46	80.0
H	8	78.5	21	78.4	34	78.0	47	73.1
J	9	68.6	22	68.9	35	79.2	48	87.5
K	10	70.7	23	67.0	36	72.7	49	75.2
L	11	77.0	24	73.7	37	73.1	50	86.8
M	12	82.6	25	94.2	38	88.7	51	92.5

Individual plots 30'x75', contain 6 rows of cane.
All treatments uniform to all plots.

Layout of Hakalau 1929 Blank Test.

Starting with a series of four plots in Row D, we find their mean yield (Y) to be 85.1 tons of cane. To this mean is attached a probable error (PEm) of 1.929 tons, while the probable error attached to any single one (PEs) of the four plots in Row D is 3.858 tons, or 4.5 per cent of their mean yield (PEs per cent).

Row	Plot No.	Yield	(d) Difference from Y	d^2
D	4	77.8	7.3	53.29
D	17	83.6	1.5	2.25
D	30	88.5	3.4	11.56
D	43	90.7	5.6	31.36

$$\text{Mean Yield (Y)} \quad \frac{340.6}{4} = 85.1 \qquad\qquad 98.46 = \Sigma d^2$$

$$\text{PEm} = .6745\sqrt{\frac{\Sigma d^2}{n(n-1)}} \qquad \text{PEs} = .6745\sqrt{\frac{\Sigma d^2}{n-1}} \qquad \text{PEs \%} = \frac{\text{PEs}}{\text{Y}}$$

$$= .6745\sqrt{\frac{98.46}{4\text{x}3}} \qquad = .6745\sqrt{\frac{98.46}{3}} \qquad = \frac{3.858}{85.1}$$

$$= 1.929 \qquad = 3.858 \qquad = .045 \text{ or } 4.5\%$$

Now, if we are to provide for more replications of our plot treatments, we must extend our total experimental area to allow for same. In consequence, we may take into our test additional soil variations, thus adding new errors.

Suppose, for example, that we now double the area of plots in Row D by adding the four adjacent plots in Row E.

A study of the next table shows that in this case the increase in the experimental area that was made to provide for additional replications was responsible for distributing the experimental errors in such a way that their effect on the results are considerably reduced. The additional area did not introduce a larger error for the individual plots, and we may assume that the soil conditions in the four plots of Row E were not widely different from those in Row D.

Row	Plot No.	Yield	d	d^2
D	4	77.8	6 3	39 6[illegible]
D	17	83 6	.5	.25
D	30	88.5	4 4	19 36
D	43	90.7	6.6	43.56
E	5	79 6	4 5	20.25
E	18	82.9	1 2	1.44
E	31	88.2	4.1	16.81
E	44	81.8	2.3	5 29

$$\text{Mean Yield (Y)} \frac{673\ 1}{8} = 84.1 \qquad \Sigma d^2 = 146\ 65$$

PEm = 1 085 PEs = 3.084 PEs % = 3.6%

A further addition of the next twelve plots in Rows F, G and H will give us a total of 20 plots, and allow for further replications. Here again, this additional area, although it introduces soil variations which slightly increase the probable error for any one of the 20 single plots over that for the 8 single plots, gives us a more reliable test area than the four original plots would have furnished, and the error of the mean yield is as we would expect, still further reduced.

Row	Plot No.	Yield	d	d^2
D	4	77.8	3 8	14.44
D	17	83 6	2 0	4.00
D	30	88 5	6 9	47.61
D	43	90.7	9 1	82.81
E	5	79.6	2 0	4.00
E	18	82.9	1.3	1.69
E	31	88.2	6 6	43.56
E	44	81.8	.2	.04
F	6	75 9	5.7	32.49
F	19	86 5	4.9	24.01
F	32	87 5	5 9	34.81
F	45	87.8	6 2	38.44
G	7	81.1	.5	.25
G	20	72.7	8 9	79.21
G	33	81.1	.5	.25
G	46	80.0	1 6	2.56
H	8	78.5	3 1	9 61

Row	Plot No.	Yield	d	d^2
H	21	78.4	3.2	10.24
H	34	78.0	3.6	12.96
H	47	73.1	8.5	72.25

$$\text{Mean Yield (Y)}\ \frac{1633.7}{20} = 81.6 \qquad \Sigma d^2 = 515.23$$

$$PEm = .910 \qquad PEs = 3.507 \qquad PEs\ \% = 4.2\%$$

With this total of 20 plots, we note in the area of land thus covered, a remarkably low probable error for a single plot, and it must be concluded that these twenty plots are located upon very uniform soil and under similar soil conditions.

The addition of four more plots in Row J, gives us an example of the limit to the reduction in probable error which may be reached by replicating the plots, when a large part of this error is due to soil variation.

Summarizing, as heretofore, the yields and differences from the mean yields, for the 24 plots in Rows D, E, F, G, H, and J, we have the following:

$$\text{Mean Yield (Y)} = \frac{1937.9}{24} = 80.7 \qquad \Sigma d^2 = 869.63$$

$$PEm = .843 \qquad PEs = 4.141 \qquad PEs\ \% = 5.1\%$$

Although the probable error of the mean yield of these 24 plots is further reduced, since the total error is now distributed over more plots, the increased area which Row J has added, has brought into the experiment some wide differences in inherent fertility, as shown by the increased probable error for the single plots.

This possibility can be still more forcibly brought to our attention if we now double this area by adding to these 24 plots, the rest of the plots (in Rows K, L, M and C, B, A) of the total "Blank Test" area studied. The 48 plots will show a summarization as follows:

$$\text{Mean Yield} = 83.1 \qquad \Sigma d^2 = 3722.95$$

$$PEm = .795 \qquad PEs = 6.003 \qquad PEs\ \% = 7.2\%$$

All of which points to the fact that there is much to be gained in reliability of experimental results by the replication of plots, *provided* that the increased area which is thereby needed, does not by itself add a greater error with its soil variation than the replications can distribute.

An Interpretation of Results of Lysimeter Experiments of Twenty Years Ago in the Light of Present-Day Knowledge on Base Exchange

By W. J. Hartung and F. E. Hance

The theory of base exchange founded on the work of Way, Lemberg, Van Bemmelen, Knop, Hissink, Gedroiz and Kelly and corroborated later by a great number of other investigators has made more intelligible the behavior of the various salts used and known as commercial fertilizers.

Thus, Pierre (1) working with a number of nitrogenous fertilizers made a critical study of the theory as applied not only to ammonium sulphate but to other forms of nitrogen as well. The particular subject on which Pierre desired clarification was that of induced soil acidity. He has so ably presented the view of investigators leading up to the subject of base exchange in relation to this induced soil acidity caused by certain nitrogenous fertilizers, that we may quote here in its entirety that portion of his work on the researches into the literature cited.

THEORIES REGARDING EFFECT OF NITROGENOUS FERTILIZERS ON SOIL ACIDITY

The effect of nitrogenous and other fertilizer salts on soil reaction has been variously explained. Mayer, as is explained in detail by Kappen, was probably the first to advance a theory regarding their action. He classified fertilizers as being physiologically acid, physiologically alkaline, and physiologically neutral, depending on whether the plant absorbed the basic part, the acid part, or both parts of the salt in its nutrition. He believed that because plants utilized the potassium of potassium chloride and not the chlorine, this salt was physiologically acid, since it left a residue of hydrochloric acid in the soil. On the other hand, sodium nitrate was considered physiologically basic, since the plant utilized the nitrate and not the sodium. These ideas of Mayer were substantiated to some extent by work with solution cultures, and some field experiments also pointed to the same conclusion.

Breazeale and LeClerc, working with wheat seedlings in solution cultures, found that the use of potassium chloride and potassium sulfate tended to leave the solution acid due to the absorption of the potassium by the plant with the consequent formation of hydrochloric and sulfuric acid, respectively.

Field work with sodium nitrate and ammonium sulfate tended to substantiate this viewpoint of Mayer, for these salts were found to decrease and increase the acidity of the soil, respectively. Hall explained the effect of ammonium sulfate as follows: "The acidity of the soil where the ammonium salts have been used is due to the attack of various molds and other micro-fungi; they seize upon the nitrogen for their own nutrition and set free the acids with which the ammonia was combined."

Ruprecht and Morse in explaining their results stated that the soil absorbs the ammonia, or that there is a double decomposition between ammonium sulfate and calcium carbonate, or some other salt, thus setting free sulfuric acid.

More recent investigations have led to the development of other variously modified theories regarding the effects of various fertilizers on soil acidity, especially with respect to ammonium sulfate. Thus, Frear states as follows in regard to ammonium sulfate: "Its continuous use inevitably tends to produce pronounced acidity in the soil. The

reasons for this are not fully understood, although it is clear that it yields two acids, nitric and sulfuric, but no base, when nitrified.''

As a result of the work at Rothamsted which showed that the addition of ammonium chloride and sulfate to a soil resulted in an almost immediate presence of chlorides and sulfates combined with calcium and magnesium in the drainage water, the new idea that two acids are formed from ammonium sulfate was expanded. Thus, it is described by Wheeler that double decomposition occurs in this reaction, that ammonia is absorbed by the soil, that the sulfate radical unites with the calcium and magnesium to be lost from the soil as such, thereby causing a loss of bases, and that a further loss of base occurs as a result of nitrification of the ammonia by which process the nitric acid formed unites with bases in the soil to be used up by the plants or lost through leaching as calcium or magnesium nitrates.

Ames and Schollenberger first emphasized the fact that it is because of the nitrification process alone that ammonium sulfate causes soils to become acid. They state, ''When a solution of potassium or ammonium salt (except the phosphate) is brought in contact with a soil, a considerable amount of the base is rapidly removed from solution and held by the soil while the acid is left in solution, free to attack any constituents of the soil which may be soluble. Although some carbonate may be lost in this way, the soil is really no poorer in bases than it was before, because whatever has been dissolved from the soil has been compensated for by the base entering the soil. In the case of ammonium sulfate, however, the absorbed base is capable of becoming acid through the process of nitrification, and a further amount of basic material will be removed from the soil.''

This view has been expanded more fully by Page who explained it according to the more recent ideas of base exchange. He emphasized the fact that nitrification is the cause of the acidity developed by ammonium sulfate and, furthermore, that it makes no difference in the acidity formed whether or not the calcium sulfate resulting from the base exchange reaction between the ammonium sulfate and the calcium complex leached out or remains in the soil. This view that nitrification rather than selective absorption of part of the fertilizer salt by the plant is the cause for the acidity developed by ammonium sulfate is further substantiated by experiments (8, 9) showing that approximately the same amounts of acidity are developed whether or not plants are growing on the soil fertilized with ammonium sulfate. Page believes that the term physiological acidity, therefore, is not strictly correct, since the action is not caused by the plant but is strictly a chemical or biological process.

Pierre, drawing on Page, then proceeds to explain the successive steps when ammonium sulfate is added to the soil:

The effect of acid forming nitrogenous fertilizers on the soil can be most easily explained, as was done by Page for ammonium sulfate, by assuming that the ammonium salt added undergoes a base exchange reaction with the absorbing complex. The absorbing complex of the soil can be represented by the formula CaX, in which Ca represents the various exchangeable bases with which the insoluble anions, X, are combined in an exchangeable form. Let it be assumed for ease of discussion that the X can only combine with one Ca. When ammonium sulfate is added to a soil the following reactions take place:

1. $(NH_4)_2SO_4 + CaX \longrightarrow CaSO_4 + (NH_4)_2X$
2. $(NH_4)_2X + O_2 \xrightarrow{\text{nitrification}} 2HNO_3 + H_2X + 2H_2O$
3. $2HNO_3 + CaX \longrightarrow Ca(NO_3)_2 + H_2X$

As a result of the reaction represented in equation 1 it is evident that no acidity is developed. Moreover, it makes little difference whether or not $CaSO_4$ is leached out of the soil, for the calcium it contains has been replaced in the exchange complex by another base, ammonium. Until nitrification, represented in equation 2, goes on no acidity is developed. As a result of nitrification it is seen that two molecules of nitric acid and

one molecule of dibasic soil acid are formed. The nitric acid may further react with another molecule of CaX, forming $CaNO_3$, in which form the nitrate may be taken up by the plant, and another molecule of H_2X formed. Thus, from one molecule of ammonium sulfate two molecules of a dibasic soil acid are eventually formed. These reactions are believed to represent quite accurately what takes place when ammonium sulfate is added to a soil, for it is well known that the absorption by the soil of the ammonia from ammonium sulfate is very rapid.

In considering the manner of development of soil acidity by additions of ammonium sulfate as outlined by Pierre, the absorption of basic radicals and acid hydrogen by soil colloids, at the same time, may also be advanced; thus in balancing Pierre's equations and totalling the products on both sides of the equality sign, we have—

$$(NH_4)_2SO_4 + CaX = CaSO_4 + (NH_4)_2X$$
$$(NH_4)_2X + 4O_2 = 2HNO_3 + H_2X + 2H_2O$$
$$2HNO_3 + CaX = Ca(NO_3)_2 + H_2X$$

$(NH_4)_2SO_4$	+	$2CaX$	+	$4O_2$	=	$CaSO_4$	+	$Ca(NO_3)_2$	+	$2H_2X$	+	$2H_2O$
fertilizer		absorbed on soil colloid		bacterial		soil solution		soil solution		replacing CaX on soil colloid (acid)		

The oxidation of the ammonium radical splits off the nitrogen which later reappears as the soluble nitrate. The hydrogen which remains is divided equally between the water formed in the reaction and as the active acid hydrogen attached to the anion X.

Thus may it be assumed that the commonly accepted "acid" constituent of the sulphate fertilizer (SO_4) is lost through leaching and that the acidity which later develops is found as the acid complex "H_2X". The adsorbed acid constituent, through the electronic attraction of its hydrogen on the soil colloid, resists leaching and perhaps functions in the soil reaction as a distinct acid body. In order to remain adsorbed on the soil colloid the concentration of hydrogen as ion must be higher in the surrounding media than any basic or other replaceable ions. This supposition may be met by accepting the very probable fact that the acid complex ionizes thus—

$$H_2X \rightleftharpoons 2\overset{+}{H} + \overset{--}{X}.$$

Hence the acidity which is finally developed may be traced in logical steps from an unlooked-for source in the ammonium or basic constituent of the sulfate nitrogen fertilizer.

We may visualize that portion of the soil capable of base exchange as Kerr (2) pictures zeolites, viz: crystalline bodies having space lattices, open in structure. The hypothetical structure shown below is intended to convey the idea of exchange presented by the above three reactions. No claim is made that the soil complex exists as indicated.

Net result, calcium entering soil solution, oxidation of ammonium in which all of the nitrogen enters soil solution as nitrate, half the hydrogen forms water and the other half becomes acid hydrogen in the complex H_2X.

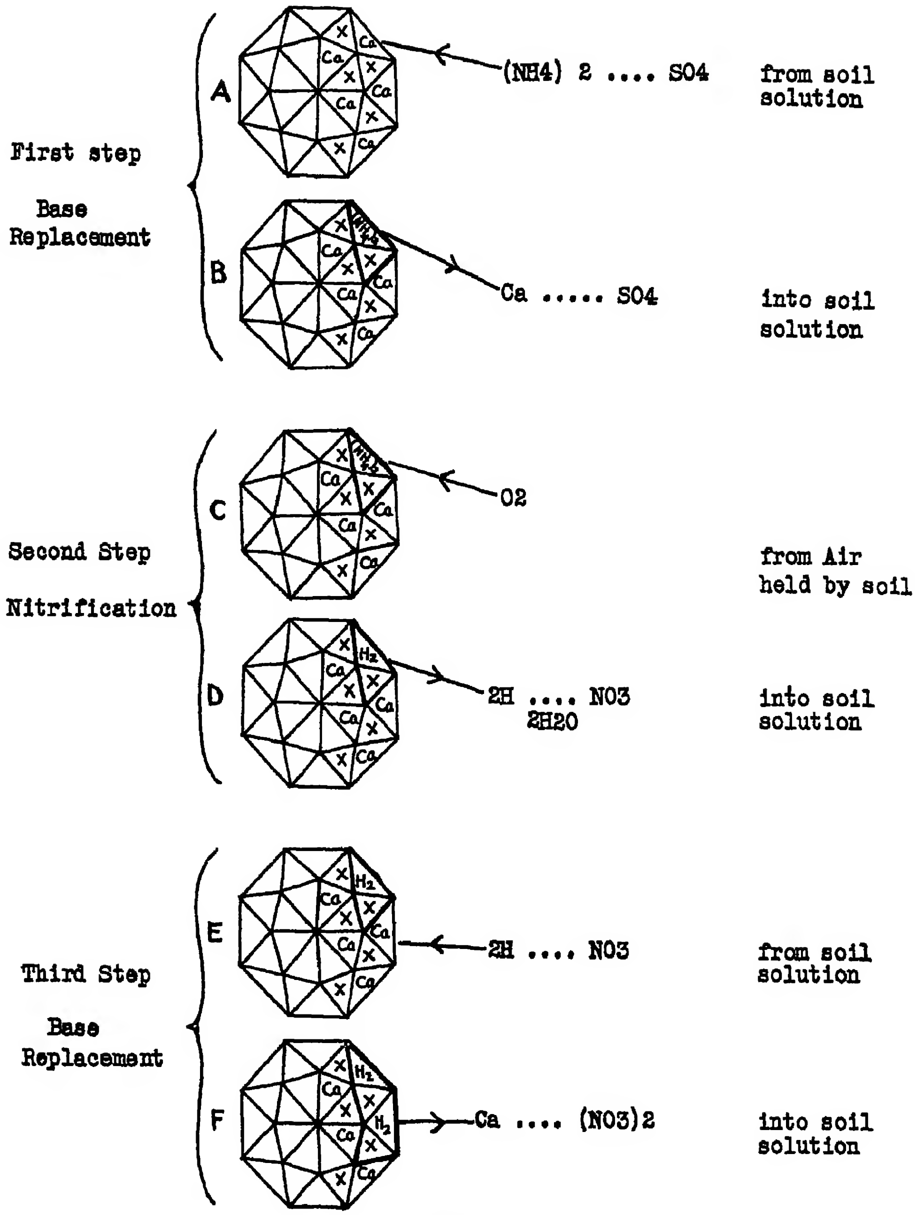

First step
Base
Replacement
A
(NH4) 2 .... S04
from soil
solution
B
Ca S04
into soil
solution
Second Step
Nitrification
C
02
from Air
held by soil
D
2H N03
2H20
into soil
solution
Third Step
Base
Replacement
E
2H N03
from soil
solution
F
Ca .... (N03)2
into soil
solution

Fig. 1

Lysimeter Experiments

Bulletins 19, 8 and 37 of the Experiment Station of the Hawaiian Sugar Planters' Association

In the first series of the work in Bulletin 19 (3), Experiment Station soil was used in testing the relative rate of nitrification of tankage, fish scrap, hoof meal, sulphate of ammonia and dried blood. Tests with nitrate of soda and with unfertilized soil were carried on concurrently. Fresh water was used in the irrigation or leaching operation. The time intervening between each successive irrigation was 7 days. The initial quantity of water applied was 20 liters per lysimeter; the next three irrigations were at the rate of 10 liters each and beginning with irrigation No. 5, 15 liters of water per lysimeter became the regular dosage. Only determinations of nitric nitrogen and lime were made on the leachate.

Data presented bearing on the loss of nitrate nitrogen and lime through leaching show that although the loss of nitric nitrogen is less in the sulphate of ammonia than in the nitrate of soda lysimeter, nevertheless sulphate of ammonia is responsible for decidedly heavier losses of lime. The writers have taken the privilege of drawing on the material of tables on pages 11 and 18 of this lysimeter work and adding to it somewhat, thus bringing out the points that bear directly on base replacement.

Table from Page 11, Bulletin 19

NITRIC NITROGEN IN DRAINAGE
Grams

Irrigation	No. 7 Check	No. 9 Nitrate Soda	No. 10 Sul. Ammonia	A Diff. (9 7)	B Diff. (10-7)
2	.88872	5.11190	1.00852	4.22318	.11980
3	.40040	7.88018	.37140	7.47978	—.02900
4	.09621	2.33056	.25401	2.23435	.15780
5	.08983	.42241	.44622	.33258	.35639
6	.08109	.12400	2.15917	.04291	2.07808
7	.10051	.12006	1.94687	.01955	1.84636
8	.09843	.13075	1.80652	.03232	1.70809
9	.12138	.15700	1.91406	.03562	1.79268
10	.12613	.14940	1.72121	.02327	1.59508
11	.19569	.19387	1.11168	—.00182	.91599
12	.11540	.19142	.70231	.07602	.58691
13	.13257	.17006	.53900	.03749	.40643
14	.12651	.18737	.37161	.06086	.24510
15	.15699	.18624	.33129	.02925	.17430
16	.11147	.13683	.24867	.02536	.13720
17	.12495	.13369	.17469	.00874	.04974
18	.08257	.08235	.12032	—.00022	.03775
19	.08221	.09947	.11771	.01726	.03550
20	.07491	.12264	.11298	.04773	.03807
21	.07056	.08581	.12952	.01525	.05896
Totals	3.27653	18.01601	15.58776	14.73948	12.31123

Explanation

Lysimeter No. 7 containing 188 pounds of Station soil only.

Lysimeter No. 9 containing 188 pounds of Station soil to the 50-pound surface layer, of which 16.3 g. of nitrogen in the form of nitrate of soda had been added.

Lysimeter No. 10 containing 188 pounds of Station soil to the 50-pound surface layer, of which 16.3 g. of nitrogen in the form of ammonium sulphate had been added.

Table from Page 18, Bulletin 19

LIME CONTAINED IN DRAINAGE

Grams

Irrigation	No. 7 Check	No. 9 Nitrate Soda	No. 10 Sul. Ammonia	C Diff. (9 7)	D Diff. (10-7)
1	......	....	......	.... .	....
2	6.05170	11.04840	6.05115	4.99670	—.00055
3	2.99585	9.99277	3.98652	6.99692	.99067
4	1.55658	3.10107	3.71574	1.54449	2.15916
5	.76217	.94605	2.62856	.18388	1.86639
6	.49484	.46046	2.67746	—.03438	2.18262
7	.41693	.38272	2.55937	—.03421	2.14244
8	.30000	.27456	2.29059	—.02544	1.99059
9	.30940	.28500	2.33906	—.02440	2.02966
10	.24612	.27272	1.77927	.02660	1.53315
11	.23707	.31446	1.36762	.07739	1.13055
12	.23026	.27346	1.00584	.04320	.77558
13	.24877	.23306	.86900	—.01571	.62023
14	.23870	.34991	.71368	.11121	.47498
15	.35956	.48327	.76734	.12371	.40778
16	.27125	.20996	.66518	—.06129	.39393
17	.27710	.20527	.55361	—.07183	.27651
18	.22213	.11340	.40108	—.10873	.17895
19	.24403	.15236	.40964	—.09167	.16561
20	.25286	.17071	.37391	—.08215	.12105
21	.30240	.16903	.44188	—.13337	.13948
Totals	16.01772	29.43864	35.59650	13.42092	19.57878

Eckart (3) does not attempt in this bulletin to give a reason for these excess amounts of lime in the leachate of the fertilized over the unfertilized check. He states: "The fact that for each pound of nitrogen added to this particular soil, 1.2 pounds of lime were rendered soluble where sulphate ammonia was used and .82 pound of lime where nitrate of soda was applied shows that the idea which is prevalent in these Islands to the effect that nitrate is the lime robber, comparatively speaking, is unfounded."

In an earlier work of the Experiment Station, H. S. P. A., (4) lysimeters, fertilized and unfertilized, were irrigated with water containing 200 grains per gallon of common salt in simulation of plantation practice where salt-bearing well water is utilized. The same soil with fresh water irrigation yielded in twenty-two irrigations but 24.80 grams of lime, whereas the salt water irrigation resulted in a leachate containing 139.15 grams of lime. Both lysimeters had had applications of fertilizer as follows: nitrogen, 20 grams from ammonium sulphate; K_2O, 10 grams from potash sulphate; and P_2O_5, 10 grams from double super. The lysimeter having no manurial treatment irrigated with saline water of same strength, yielded 120.22 grams of lime. It is quite apparent that sodium chloride in the water has acted as the replacing agent and (Na) has taken the place of (Ca) in the soil complex. In addition the ammonia radical has behaved similarly, viz., replacing more calcium and later on nitrification resulting in still greater quantities of lime going into the leachate.

Eckart is quite near to the present day interpretation when he states, "When a solution of various salts is allowed to remain in contact with a soil for any length of time, the latter exchanges certain of its elements for those in the salt solution."

In the lysimeter experiments conducted by Peck (5) on "upland soil," with nitrogen added all as sulphate of ammonia, again as in the previous work a very heavy lime content was found in the leachate of those lysimeters which had an application of nitrogen in this form alone. Peck in his discussion touches on replacement thus: "This increase may have been due to a substitution by the ammonia of calcium in the soil, the formation of soluble calcium sulphate and its recovery in the leachings, or the increased nitric oxide formed during nitrification combining with the lime in the soil the soluble amount, or again it may be the combined effect of both reactions."

Fig. 2 graphically presents tabulated reworked data of columns A and C. The plotted values indicate quite convincingly the replacement of the soil calcium by the sodium contained in the nitrate of soda. Thus the nitrate nitrogen in the drainage was without question largely calcium nitrate.

In Fig. 3, where nitrogen was added to the soil in the form of ammonium sulphate, the curves reveal the base exchange step as well as subsequent nitrification and a second replacement. Thus we note that although no nitric nitrogen appears in the first three irrigations, calcium is found in the drainage in relatively large quantities. When nitrification is well under way we find that the two lines (B and D) all but coincide. Unfortunately, no (SO_4) determinations were made on the leachate yet we may visualize the base exchange (Step 1) illustrated in drawings above as having taken place at once with the calcium making its appearance in the subsequent drainage waters very probably in the sulphate form. And that on nitrification of the ammonia (Step 2) there follows immediately a further replacement (Step 3) resulting in the presence of calcium nitrate in the drainage as indicated by the close correlation of the lime and nitric nitrogen lines.

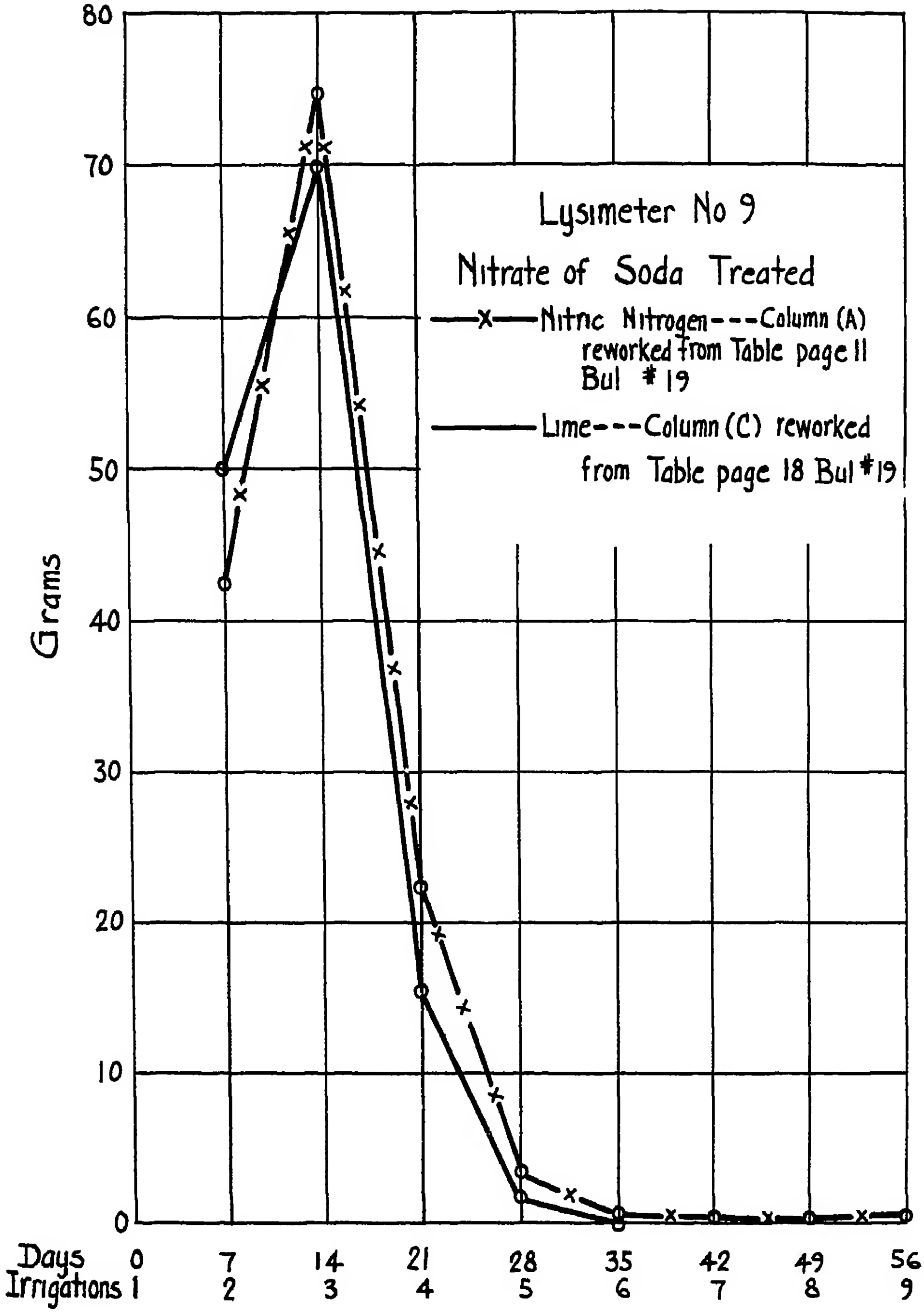
Fig. 4 illustrates the nitric nitrogen and lime behavior where ammonium sulphate had been applied to upland soil, Peck (5). The curves represent the excess of nitric nitrogen and lime removed through irrigations with distilled water, lysimeter No. 5 The method followed by Peck was similar to that followed by Eckart. However, instead of tubs, cylinders 2 feet in height and 8 inches in diameter were employed. Irrigations were made every 14 days instead of every 7 days using distilled water as against fresh. Each lysimeter had but 25 pounds of soil and .57 gram of added nitrogen. Working with these small quantities the curves are almost a duplication of those illustrated in Fig. 3. This soil shows a relatively low lime content (aspartic acid method) but is very high in total magnesia. Whereas the soil used in lysimeter No. 17 nitric nitrogen and lime, curves of which appear in Fig. 5, had been previously limed and yielded a high aspartic acid lime content in comparison thus:

ASPARTIC ACID METHOD

	Upland Soil	Lowland Soil
Lime (CaO)	0.035 per cent	0.290 per cent

Soluble in Strong Hydrochloric Acid (O. A. C. Method)

Lime (CaO)	.85 per cent	.84 per cent
Magnesia (MgO)	2.47 per cent	.84 per cent



Lysimeter No 9
Nitrate of Soda Treated
—x— Nitric Nitrogen---Column (A) reworked from Table page 11 Bul #19
—— Lime---Column (C) reworked from Table page 18 Bul #19
Grams
80
70
60
50
40
30
20
10
0
Days 0 7 14 21 28 35 42 49 56
Irrigations 1 2 3 4 5 6 7 8 9

Fig 2

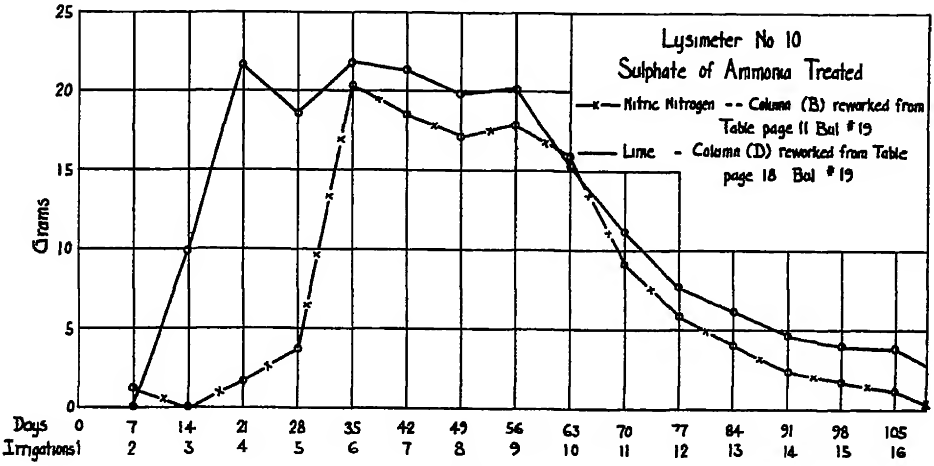


Fig 3

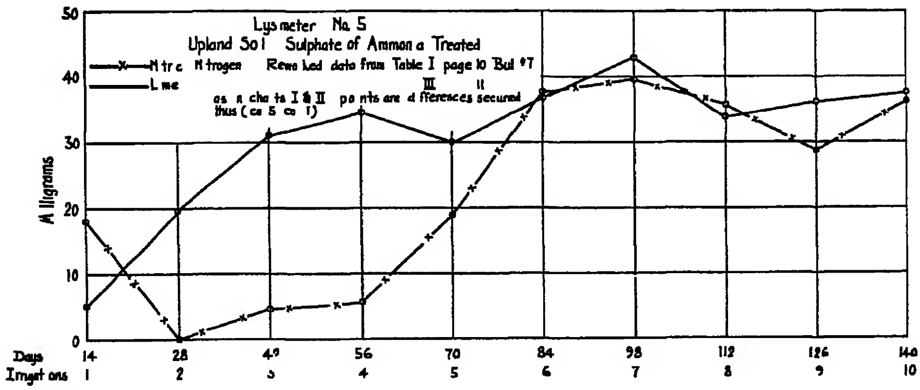


Fig 4

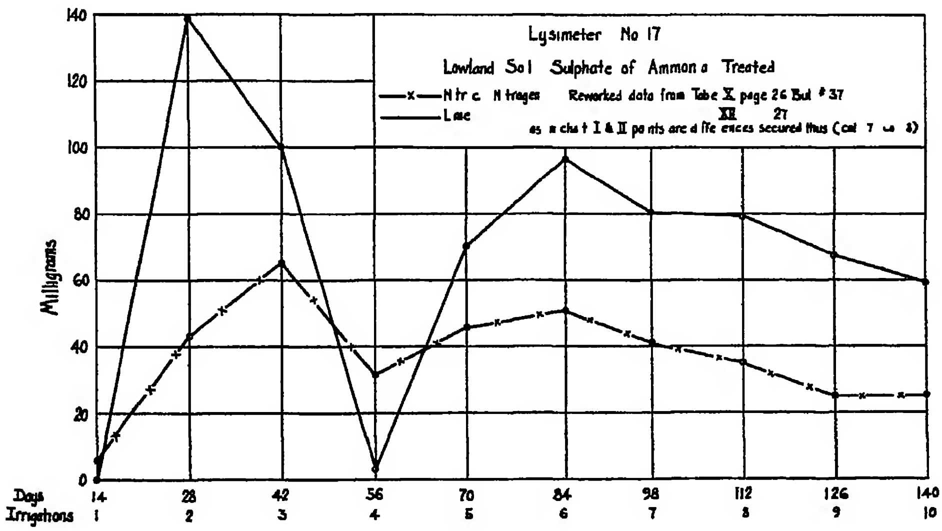


Fig 5

The lime as indicated by aspartic acid method is in all probability replaceable. We may therefore attribute the irregularity in the lime curve, Fig 5, to this high replaceable lime. Nitrification, too, was rather rapid, which would account for the excessive lime in the leachate when added to that resulting from S ep 1 in replacement. There is one lime determination, the fourth irrigation, much at variance, for which apparently no explanation exists All other points, with the exception mentioned, when connected up present curves that indicate a close relationship existing between the lime and the nitric nitrogen.

We have confined our interpretation to the lime and nitric nitrogen figures only. The bulletins referred to contain data on potash in these lysimeter drainage waters which likewise present a very interesting study from the standpoint of base exchange. For example, a table on page 25 of Bulletin 19, comparing the action of different forms of lime, shows that where gypsum is used in the soil the drainage from the lysimeter contains 80 per cent more K_2O than is found in the drainage of the check lysimeter.

Conclusion

Although these data, appearing in bulletins cited, are insufficient proof that the reactions are those of base replacement, yet they do furnish very striking evidence that just such changes have occurred.

It is evident that a great deal of value may be gleaned through study of old lysimeter data; also that still more may be added to our knowledge of fertilizers by more lysimeter experiments, well planned and carefully conducted. Lysimeters offer a ready method in base exchange and soil solution studies. It is quite apparent that to provide for thoroughness, treatments should be in replications of three or more; that there be tests on the degree of acidity or alkalinity of the soil and all drainage waters; that determinations be made of other cations and anions, of soil colloids, and of the replaceables, on the soil and soil solution under investigation. This is particularly important in fertilizer studies. A great many of our newer forms of nitrogen could be tested very speedily in this manner and the information secured would have a practical value as well as an academic value.

The rearrangement of and deduction made from Eckart's and Peck's data at this late date for the purpose of illustrating quantitative replacement phenomenon occasion the authors considerable satisfaction in finding such painstaking accuracy in detail and technique in investigational work of a previous decade.

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The Properties of the Tissue Fluids of Sugar Cane in Their Possible Relation to Drought Resistance

By J. Arthur Harris* and H. Atherton Lee†

Introduction

The factors which determine the differences in the capacities of varieties of agricultural plants to resist drought are so complex that they can be differentiated only by critical scientific experimentation of the most diverse kinds. The importance of the problem, both from the standpoint of scientific theory and agricultural practice, is so great that it justifies every effort to disentangle this complex of factors, and to express them in terms of quantitative science.

Breeding for drought resistance must remain a purely empirical undertaking until the exact physiological and structural factors determining drought resistance are actually ascertained

The purpose of this paper is to present a limited series of determinations made on the tissue fluids of seven varieties of cane grown under comparable conditions on the grounds of the Experiment Station of the Hawaiian Sugar Planters' Association in Honolulu in the summer of 1924, and to suggest the possible bearing of the results thus obtained on the problem of drought resistance in cane.

The theory underlying the interpretation of these results rests largely on studies of the vegetation of climatically diverse regions. These must be briefly reviewed as a background for the conclusions drawn from these preliminary studies of sugar cane.

From the standpoint of chemical and physiological theory it might be assumed that the capacity of the plant to develop under conditions of aridity or high salinity may be in some degree dependent on the osmotic pressure or osmotic concentration of its tissue fluids. It is to be assumed that the magnitude of this concentration is a factor of importance in determining the capacity of the plant for the withdrawal of water from the soil. The pioneer studies of Drabble and Drabble (1) in English habitats and of Fitting (2) in the extreme conditions of the North African deserts tend to support this view.

The studies by Drabble and Drabble and by Fitting were carried out by methods not capable of yielding the most precise results. They have been followed by measurements made by more exact physical means in a widely diversified series of plant habitants. Measurements of the osmotic concentration of the tissue fluids of native plants have been made by the freezing point method in the Arizona deserts (3), in the highly saline deserts of the Lake Bonneville Basin (4), in the coastal deserts of Jamaica (5), and in the Mangrove swamp (6).

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These studies, which have been in part reverified by studies on the native vegetation of the more arid portions of Oahu, T. H., have shown that the plants of arid and saline regions are characterized by a higher osmotic concentration of their tissue fluids than those of the moister habitats of the eastern United States (7), where electrical conductivity of the sap has also been investigated (8), and of the Montane Rain Forest of Jamaica (9).

The results of these studies have been confirmed by (as yet unpublished) investigations in the subtropical jungles of southern Florida, and by preliminary studies in the rain-forests of Oahu.

The results of these investigations, which have been reinforced by parallel studies on the osmotic concentration (10) and on the electrical conductivity (11) of the tissue fluids of epiphytic plants, i. e., of the so-called "air plants," fully justify the conclusion that the capacity of the plant for withdrawing water from arid or saline soil is in some degree dependent on the concentration of its tissue fluids. They early led to the conclusion that physicochemical measurements on the plant tissue fluids should play an important role in plant geographical investigations (12).

If this conclusion be valid, it should be found that the osmotic concentration of the tissue fluids of parasitic plants is higher than that of the hosts. This is the conclusion reached by Senn (13) and by wholly independent studies of our own on the osmotic concentration of rain-forest (14) and desert Loranthaceae (15) parasitic on various host plants, and on the electrical conductivity of the tissue fluids of desert mistletoes (16). Further evidence in the same direction may be furnished by our demonstration (17), confirmed by the work of other authors, that the osmotic concentration of the leaf tissue fluids increases with the height of leaf insertion in trees.

That these relationships between parasite and host do not obtain universally is shown by the fact that in the dodder, *Cuscuta*, the osmotic concentration and electrical conductivity of the parasite may be lower than that of the host plant (18).

Since the plant species which constitute the natural vegetation of regions which differ greatly in the aridity or salinity of the soil have been shown to differ in the physicochemical properties of their tissue fluids, it would seem quite reasonable to assume that the properties of the tissue fluids of crop plants may be of importance in determining the possibility of their growth and productiveness under the varying soil and atmospheric conditions of different regions. These studies have, therefore, been extended to a number of agricultural plants.

Harris and Popenoe considered the osmotic concentration of the tissue fluids of the avocado in their possible relation to frost resistance (19).

The most extensive studies have been those based on Egyptian and Upland cotton as grown under irrigation in the arid regions of the United States. In these studies it has been shown that Pima Egyptian cotton has a higher osmotic concentration, specific electrical conductivity and hydrogen-ion concentration than either Meade or Acala Upland cotton (20). This differentiation of the Egyptian and Upland type seems to be general, since it has been found to hold for a number

of varieties of the Egyptian type recently introduced from Egypt into the United States (21).

The differentiation of these two types is not limited to the total solutes of the sap or to the concentration of all electrolytes, but is found to obtain specifically for chlorides (22) and for sulphates (23). The absorption of these anions has been shown to be differential (24). Furthermore the rate of accumulation of chlorides in the Egyptian types seems to be more rapid than in the Upland type. There are evidences for definite behavior of certain of these tissue fluid properties in hybridization.

Preliminary Results for Sugar Cane

The osmotic concentration of the tissue fluids is most readily and accurately measured by determining the freezing point depression, i. e., the difference between the freezing point of the tissue fluid and that of pure water. Osmotic concentration is then calculated by G. N. Lewis' formula:

$$P = 12.06\,\Delta - .021\,\Delta^2$$

where P is the osmotic concentration in atmospheres and Δ is the freezing point depression of the sap, corrected for the amount of ice separating because of undercooling (25).

Freezing point depression was determined on saps extracted by pressure after antecedent freezing in an ice-salt mixture to increase the permeability of the tissues as has been shown to be necessary by Dixon and Atkins (26) and by ourselves (27) and others.

Samples were taken from plants of seven varieties of cane grown on the Honolulu grounds of the Experiment Station of the Hawaiian Sugar Planters' Association. All plants were under conditions as nearly comparable as could be secured. Leaf samples were taken from the third, fourth and fifth leaves from the tip of the stalk. Samples of stalks were taken from the lowest nodes in order to secure as nearly comparable materials as possible.

The cultures on the Experiment Station grounds were very limited in extent and the plants were required for other purposes. Samples were, therefore, restricted to a very few stalks. As a result of this necessary limitation, the constants show the irregularities which are generally found when measurements are based on samples of limited size. This difficulty can be overcome only by carrying out the investigations on a larger scale.

The varieties employed and the dates of collection are given in the accompanying tables.

Table I shows the freezing point depression in degrees centigrade of the leaf tissue fluids of the seven varieties of cane as determined on six different dates. For the purpose of bringing out clearly the relative values of osmotic concentration in the different varieties, the names of the varieties have been given under each date in the order of the freezing point depression, from the highest to the lowest value. Table II gives the same results calculated in terms of atmospheres of osmotic pressure, P.

In examining these resul's one must be impressed by the fact that the leaf tissue fluids of Uba are characterized by higher osmotic concentration than those of any other of the seven varieties considered. While the differences between varieties are in all cases small, Uba stands at the head of the list in each of the six series of determinations made. The other varieties show considerable irregularities, as might be expected when determinations are based upon a very limited amount of material as was necessary in the present case.

If we consider the average values of the constants for the six determinations we have the following results:

Variety of Cane	Freezing Point Depression	Osmotic Concentration
Uba	0.823	9.91
Badila	0.701	8.44
Yellow Caledonia	0.693	8.35
H-109	0.682	8.21
D-1135	0.679	8.18
Lahaina	0.649	7.82
Yellow Tip	0.646	7.78

The difference between the average constant for Uba and the highest of the other varieties is 0.122°, or 1.47 atmospheres. The difference between the highest (Badila) and the lowest (Yellow Tip) constant for varieties other than Uba is only 0.055°, or 0.66 atmosphere.

The freezing point depressions of the juice from the basal nodes of the stem are arranged in order in Table III. The results are expressed in terms of atmospheres pressure in Table IV.

TABLE I

Freezing Point Depression of the Leaf Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

Aug. 29	Sept. 5	Sept. 16	Sept. 17	Sept. 19	Oct. 1
Uba .984	Uba .855	Uba .826	Uba .763	Uba .746	Uba .765
Lahaina .752	Badila .753	Yellow Caledonia .757	H 109 .735	Badila .676	H 109 .719
Badila .749	D 1135 .727	D 1135 .717	D 1135 .714	H 109 .670	Lahaina .712
Yellow Caledonia .723	Yellow Caledonia .696	H 109 .708	Yellow Caledonia .693	D 1135 .640	Badila .688
Yellow Tip .685	Yellow Tip .669	Badila .686	Badila .654	Yellow Tip .611	Yellow Caledonia .681
D 1135 .688	Lahaina .608	Lahaina .667	Yellow Tip .639	Yellow Caledonia .608	Yellow Tip .626
H 109 .659	H 109 .598	Yellow Tip .647	Lahaina .604	Lahaina .553	D 1135 .609

TABLE II

Calculated Osmotic Concentration in Atmospheres of the Leaf Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

Aug. 29	Sept. 5	Sept. 16	Sept. 17	Sept. 19	Oct. 1
Uba 11.850	Uba 10.290	Uba 9.936	Uba 9.195	Uba 8.991	Uba 9.213
Lahaina 9.057	Badila 9 069	Yellow Caledonia 9.117	H 109 8.852	Badila 8.143	H 109 8.660
Badila 9.021	D 1135 8.756	D 1135 8.642	D 1135 8.600	H 109 8.065	Lahaina 8.576
Yellow Caledonia 8.708	Yellow Caledonia 8.383	H 109 8.528	Yellow Caledonia 8.353	D 1135 7.710	Badila 8.281
Yellow Tip 8.251	Yellow Tip 8.065	Badila 8.269	Badila 7.872	Yellow Tip 7.355	Yellow Caledonia 8.203
D 1135 8.046	Lahaina 7.324	Lahaina 8.034	Yellow Tip 7.691	Yellow Caledonia 7.330	Yellow Tip 7.541
H 109 7.938	H 109 7.198	Yellow Tip 7.800	Lahaina 7.282	Lahaina 6.657	D 1135 7.337

TABLE III

Freezing Point Depression of the Stalk Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

Aug. 29	Sept. 5	Sept. 16	Sept. 17	Sept. 19	Oct. 1
Uba 1.422	Uba 1.532	Uba 1.642	Uba 1.603	Uba 1.606	Uba 1.611
Lahaina 1.403	Yellow Caledonia 1.520	Yellow Caledonia 1.571	Yellow Caledonia 1.392	Badila 1.573	H 109 1.393
Yellow Caledonia 1.374	Lahaina 1.379	Badila 1.470	D 1135 1.250	Yellow Caledonia 1.520	D 1135 1.351
H 109 1.208	H 109 1.227	Yellow Tip 1.298	H 109 1.221	H 109 1.337	Yellow Caledonia 1.342
D 1135 1.162	Badila 1.221	D 1135 1.274	Badila 1.216	Lahaina 1.139	Lahaina 1.310
Yellow Tip 1.102	Yellow Tip 1.144	H 109 1.159	Yellow Tip 1.184	Yellow Tip 1.083	Badila 1.227
Badila 1.098	D 1135 1.075	Lahaina 1.101	Lahaina 1.135	D 1135 .878	Yellow Tip 1.191

TABLE IV

Calculated Osmotic Concentration in Atmospheres of the Stalk Tissue Fluids of Seven Varieties of Cane Arranged in the Order of Their Magnitudes

Aug. 29	Sept. 5	Sept. 16	Sept. 17	Sept. 19	Oct. 1
Uba 17.10	Uba 18.42	Uba 19.75	Uba 19.28	Uba 19.31	Uba 19.37
Lahaina 16.88	Yellow Caledonia 18.27	Yellow Caledonia 18.89	Yellow Caledonia 16.74	Badila 18.92	H 109 16.76
Yellow Caledonia 16.53	Lahaina 16.59	Badila 17.68	D 1135 15.05	Yellow Caledonia 18.29	D 1135 16.25
H 109 14.54	H 109 14.76	Yellow Tip 15.61	H 109 14.70	H 109 16.08	Yellow Caledonia 16.14
D 1135 13.98	Badila 14.68	D 1135 15.32	Badila 14.63	Lahaina 13.71	Lahaina 15.76
Yellow Tip 13.27	Yellow Tip 13.77	H 109 13.94	Yellow Tip 14.24	Yellow Tip 13.04	Badila 14.76
Badila 13.21	D 1135 12.94	Lahaina 13.25	Lahaina 13.65	D 1135 10.56	Yellow Tip 14.34

Again we note that in every series of determinations the highest osmotic concentrations are found in Uba.

The averages for the six determinations available for each variety are:

Variety of Cane	Freezing Point Depression	Osmotic Concentration
Uba	1.569	18.87
Yellow Caledonia	1.453	17.48
Badila	1.301	15.65
H-109	1.257	15.13
Lahaina	1.245	14.97
Yellow Tip	1.167	14.05
D 1135	1.165	14.02

In both series of averages (for leaves and stems) Uba stands at the head of the list, and is followed by Yellow Caledonia and Badila, but the order of these two latter is reversed in the case of the determinations on leaves and stems. In both cases H 109 occupies the fourth position. Lahaina, D 1135 and Yellow Tip show the lowest values in the determinations on leaves and stems.

Judged by purely physiological standards the conclusions to be drawn from these meager data would be that Uba should be the most drought resistant of the seven varieties considered, while H 109 should occupy an intermediate position between Uba, Yellow Caledonia and Badila on the one hand and Lahaina, Yellow Tip and D 1135 on the other, the three latter together with H 109 presumably representing the least drought resistant varieties of the seven considered.

Discussion of Results

The foregoing conclusions were based entirely upon a study of the tissue fluids. Comparing these results with practical experience in the growing of sugar cane, one is led to the conclusion that osmotic pressure of either the leaf or cane stalk juices is correlated to a certain degree with drought resistance.

The Uba variety is without doubt the most drought-resistant cane grown in the Hawaiian Islands and, as the tables of results show, has the greatest freezing point depression and highest osmotic concentration of any of the other varieties by a considerable margin. Moreover, the Lahaina variety, which has a low freezing point depression and osmotic concentration, is without question a sensitive variety to drought. On the other hand, D 1135 and Yellow Tip are canes that grow normally under unirrigated conditions and have drought resistance. W. P. Naquin, from his observations in Hamakua, places Uba first in drought resistance, D 1135 second, and Yellow Caledonia third, followed by Yellow Tip and H 109. "Growth measurements," he says, "made during several dry spells in this district showed that these canes ran about as above. I believe that Mr. Jennings found at Kohala that Yellow Tip was far less resistant to dry weather than D 1135, although Yellow Tip kept green very much longer than D 1135. The growth, however, was checked very much more rapidly with the Tip."

Too much stress must not be laid on these results until confirmed by more extensive series of determinations and more adequate tests of relative drought re-

sistance under the conditions of he growing of sugar cane. It is a question for further endeavor to attempt to utilize osmotic concentration determinations in actual practice to predetermine the drought resistance of a new variety. The writers feel that these preliminary attempts of such prediction should at least be put on record for the use of future investigators.

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The Chemical and Physical Properties of Ewa Plantation Soils as Influenced by Irrigation With Artesian Water, With Special Reference to Drainage

By W. T. McGeorge

One phase of the irrigation problem at Ewa Plantation is that it has been confronted in several of its fields with badly puddled and poorly drained soil types, a high water table and salt accumulation. In view of this the plantation management was interested to learn, on the basis of new developments in soil science, the present status of their soils and what will be the ultimate effect of continuously irrigating with saline waters. The work presented in this paper was planned at a conference of Messrs. George F. Renton, W. P. Alexander and J. D. Bond, of the plantation staff, and the writer, and is presented in this form in the Record because its application is general for Island conditions. The writer is indebted to these members of the plantation staff for their hearty cooperation in this work.

One of the important problems affecting the fertility on irrigated plantations is the presence of salt in the irrigation water and its accumulation in the soil. In the past we have devoted considerable time and effort to this problem in an attempt to increase our knowledge and understanding of its many phases. In two previous articles (1) the writer has dealt at some length upon the presence of salt in our irrigated fields, and some physiological effects of excess salt accumulation upon cane growth. The investigations of our predecessors, Maxwell, Eckart, Peck and Burgess, have also been reviewed and presented in abstract. In their work, as well as our own, there is conclusive evidence of a salt accumulation in a number of Island areas which has exceeded the limit of tolerance of some cane varieties. These studies have demonstrated the outstanding property of H 109 to resist the toxic effect of high concentrations of salt in the soil solution. While a knowledge of salt accumulation and its physiological effect upon cane growth is of interest and value, the problem is incomplete without some knowledge of the effect upon soil properties, such as the present and ultimate changes in mechanical condition and chemical composition.

With few exceptions the soil fertility of agricultural districts has received many serious setbacks in the United States and in foreign countries where rainfall is insufficient and must be supplemented by artificial irrigation. Many of our own fields have been under irrigation for forty years or more. What then is the present status of these soils as compared with irrigated areas in other countries, and can we offer an estimate of what the ultimate effect of saline irrigation water will be on our own fields? Or better still, can we offer suggestions which will help us to avoid the difficulties others have encountered? To date we have had few really

serious alkali soil problems. In the United States, as well as in several foreign countries, many of the outstanding leaders in soil science have been occupied with this problem and some remarkable progress has been made. As a result of their investigations, we now have a rather definite understanding of the chemical and physical changes taking place in soils where it is necessary to resort to irrigation to meet the water requirement of the crop.

The most fertile soils are, in the main, well satisfied, chemically, with calcium. It has been known for seventy-five years or more that soils possess the property of fixing bases such as calcium, magnesium, sodium, potassium. Our present knowledge of the nature of this fixation and an appreciation of its value has aided greatly in identifying the cause and nature of soil peculiarities. The theory of this phenomenon has been previously dealt with in some detail in the *Record*. Suffice it to say here that the so-called fixed bases are subject to replacement by other bases added in fertilizer or irrigation water, and that if best fertility is to be maintained an effort should be made to retain calcium as the predominating fixed base. Such highly hydrolytic bases as magnesium or sodium, if they reach certain proportions, will seriously injure or completely destroy the fertility of the soil. We then have a soil state which is classified as one of the alkali types.

As already stated, toxic concentrations of salt have been found in some of our plantation soils. Both Peck and Burgess obtained evidence of sodium carbonate in Island soils, but unfortunately, they were not equipped at that time with our present methods and apparatus to determine its degree. Alkali soils were classified then as of one of two types, namely, white alkali or black alkali. The former included all types containing salts other than sodium carbonate, and the latter included sodium carbonate which, due to its solvent action toward organic matter, gave a black soil solution. We no longer look upon alkali soils as being unrelated types but rather as soils in different degrees of sodium or magnesium saturation with or without an accumulation of salines. In fact, so-called black alkali soils may contain no sodium carbonate, as shown by de'Sigmond (2) and by Breazeale and McGeorge (3), but they may have an alkalinity entirely derived from the hydrolysis of "fixed" sodium. Then, too, as shown by de'Sigmond (2), black alkali soils may be practically free of soluble salts. It is just a short step, therefore, under certain cultural practices, from a white alkali to a black alkali type if sodium is the predominating base, and this type of soil is very difficult to reclaim.

de'Sigmond (2) gives three factors which are responsible for the change from non-injurious saline types to undesirable alkali types, as follows:

1. Arid or semi-arid climate.
2. Impervious subsoil.
3. Peculiar hydrological circumstances enabling a superabundance of water in the soil intersected by dry periods.

Kelley (4) emphasizes the (a) use of saline irrigation water and (b) high water table from excessive irrigation as being major causes of alkali formation and he points out that waters not excessively saline have often caused undesirable alkaline conditions. Hilgard regarded an arid climate as related to alkali soil

formation but de'Sigmond points out that even in very arid climates soils are fertile if they are permeable.

The writer believes it to be a very good policy to consider the alkali problem from two rather closely defined angles, namely, (a) an accumulation of excessive quantities of salt to produce a soil solution of toxic concentration, and (b) a soil condition of relative impermeability caused by the well-known property of alkali (hydroxyl ion) to convert clay into a highly dispersed state which closes the pore spaces of the soil and seriously limits aeration and permeability. It is in the second class that the more serious troubles arise. Many saline irrigation waters may be entirely free of any injurious effects upon the soil or plant and, if permeability is maintained and water judiciously applied, soil fertility will be permanent. Such waters are mainly high calcium waters. On the other hand, high sodium or magnesium waters usually result in undesirable soil conditions.

A description of the process by which irrigation waters may injure or improve soils may be of interest at this point. The compounds which impart to soils the property of base fixation and base exchange* are known as zeolites and believed to be complex silicates of colloidal dimensions. They are sometimes referred to in soils as the exchange complex. When a salt solution or irrigation water of basic composi ion different from that of the fixed soil bases is brought in contact with the exchange complex of the soil, there will be an exchange of the predominant base of the solution for that of the exchange complex of the soil. That is, if the zeolite base of the soil is in greatest part calcium and the soil is irrigated with a high sodium water, the calcium will be replaced in whole or in part and leached away in the drainage while its place in the exchange complex will be taken by sodium. The exchange reaction is practically instantaneous. The relative affinity of the exchange complex for the different bases stands in the following order: $Ca > Mg > K > Na$, while the relative degree of clay dispersion, as well as hydration of respective ions, stands in the following and opposite order: $Na > K > Mg > Ca$. It may be seen from the above why high calcium soils are normal soils and vice versa from the lower affinity for sodium, why this type of soil is abnormal and only formed when a relatively large excess of sodium is present in the soil solution.

Conditions at Ewa and Outline of Problem

Rainfall at Ewa Plantation Company averages about 20 inches per annum. Pump waters only are used for irrigation. In some fields a high water table has interfered with cane ripening, and in these fields tile drains have been installed to lower this water table. The soils include heavy adobe clays, friable clay loams and a number of "coral" types. The salt accumulation varies from practically nil to toxic concentrations. For investigation the problem was divided into four phases as follows:

1. The present composition of the soil zeolites at Ewa and the nature and amount of salt accumulation.

* The fixed or replaceable bases will be referred to as zeolite bases throughout this paper.

2. The tile drainage system and the changes taking place in the soil as a result of their installation

3. The quality of Ewa irrigation waters as compared with a number of mainland waters of known value.

4. Remedial measures for the correction and removal of undesirable accumulations of magnesium and sodium

Zeolites in Ewa Soils

As an initial step a number of fields were selected and soil samples obtained, some being sampled to a depth of only one foot and others to three or four feet. All samples were taken with a soil auger and three to six borings per sample, depending upon the size of the area. The following is a description of the soils.

1. Field 19B—red silty clay loam, no coral, good drainage, fertile field

2. Field 26B—blackish clay, drainage only fair, surface layer caked. This field is irrigated with a water high in magnesium.

3. Field 17A—red silty clay loam, good field and good drainage

4. Field 3D—this field had recently been tiled. A blackish clay; many spots in the field were poorly drained. This sample taken near drain well where cane growth was excellent and drainage fair; salt efflorescence in some areas.

4b. Subsoil to 4, second foot, slightly heavier than 4.

5. A bad spot in field 3D where drainage is poor.

6. Fair spot in field 3D.

7. Bad spot in field 3D.

9 Field 21A—red silty clay loam, good drainage, no coral

10. Field 21A—same as 9, except taken in area where there is considerable coral.

Samples 11, 12, 13 and 14 were taken from good and bad spots in field 11, which has been tile drained for five years, originally had high water table.

11. Heavy clay, poorly drained, cane making poor growth.

11b. Second foot to 11.

11c. Third foot to 11.

12. Same type as 11 but better drained and cane making good growth.

12b. Second foot to 12.

12c. Third foot to 12.

13. Same type as 11, practically no germination (ratoons) in this area, drainage poor and some salt efflorescence.

13b. Second foot to 13.

13c. Third foot to 13.

14. Same type as 11, good area, good drainage, good cane growth.

14b. Second foot to 14.

14c. Third foot to 14.

15. Same type as 11, field 14.

15b. Second foot to 15.

15c. Third foot to 15.

16. Field C, heavy clay soil, highly dispersed, considerable salt accumulation, cane germinates very poorly or not at all, tile drains recently installed

16b. Second foot to 16.

16c. Third foot to 16.

17. Field C, same type as 16, sample taken near drainage well where drainage is good and cane growth fair.

17b Second foot to 17.

17c. Third foot to 17.

18. Red clay loam taken in camp near field 11, not cultivated

19. Field A, red clay loam, poorly drained area

19b. Second foot to 19.

19c. Third foot to 19.

20. Field A, poorly drained area, same type as 19.

20b. Second foot to 20.

20c. Third foot to 20.

20d. Fourth foot to 20, this sample represents a hardpan at the four-foot level.

21. Field A, well drained area, same type as 19.

21b. Second foot to 21.

21c. Third foot to 21.

Samples 22 to 26, inclusive, were taken in the peninsular fields of Oahu Sugar Company as representative of the black adobe type with coral rock.

22. A good area, coral

23. A poor area, no coral.

24. A good area, coral.

25. A poor area, no coral.

26. A good area, coral.

The complex which goes to make up a soil is often divided into active and passive constituents. The latter includes the practically inert materials which serve as a soil skeleton functioning largely as a mechanical support for the plant, and by disintegration and decomposition to form the active constituents. The former include the available forms of plant food, the soluble constituents of the soil solution and the insoluble constituents which are fixed by the soil in forms that will react chemically with bases present in the soil solution, that is, the soil zeolites. Our examination of the preceding soils has covered only the active constituents.

Most of the soil samples were too badly puddled to permit obtaining the soil solution by displacement. For this reason the relative soluble salt content was determined by analyzing a 1:5 water extract and calculating back to a basis of a soil solution of 20 per cent moisture content, which is about optimum for these soils. While this does not represent the true soil solution, the results are comparative. The zeolite bases were determined by replacement with both barium chloride and ammonium chloride. The results of these analyses are given in

Tables I and II. The zeolite bases are expressed as per cent in dry soil, ratio of each base to the sum of the bases, and as milliequivalents* per 100 grams of soil.

Before attempting to interpret the data in these tables it is of interest to present some similar analyses of soils from other sources and of known properties. The following are taken from data obtained by Kelley (5) from a number of soils from California, Arizona, Nevada, Utah and Idaho, which he has separated into poor and intermediate alkali soils and into good soils:

	Per Cent Dry Soil	Per Cent of Total Bases
Bad alkali soils—		
Calcium	.0 –.079	0–14
Magnesium	.0 –.113	0–31
Sodium	.082–.842	50–97
Intermediate alkali soils—		
Calcium	.158–.261	36–52
Magnesium	.0 –.098	0–30
Sodium	.094–.153	22–32
Good soils—		
Calcium	.151–.594	53–80
Magnesium	.062–.162	16–38
Sodium	.005–.047	1–9

Normal soils of the temperate zone usually contain 80-90 per cent calcium with small amounts of magnesium, sodium and potassium.

Fields 19B, 17A, 21A and 14 are all good fields and, as compared with mainland soils, would be classed as good soils, or at least better than intermediate saline types. In other words, there is no evidence that saline irrigation or the use of nitrate of soda has caused any rapid progressive soil changes in well-drained fields.

All the rest of the fields examined were selected for abnormal types. In Field 26B there is an abnormally high percentage of zeolite magnesium and this has greatly affected the mechanical texture of the soil. The clay is highly dispersed and this has materially retarded drainage. Also, the soil "cakes" considerably on drying.

Field A, located in the Apokaa Section of the plantation, has given some trouble to the irrigators on account of the difference in the rate at which different sections of the field take water. Samples of soil were taken from two poorly drained areas and from one good area. In two cases the first, second and third foot were sampled. In the third case the fourth foot was also sampled as a clay hardpan was found below the third foot in the poorly drained areas, and this latter is represented by 20d. The principal difference between the poor and well-drained areas is in the acidity (replaceable hydrogen) in the subsoils of the former. On the whole, though, there is a higher percentage of zeolite calcium and lower sodium in the good area. The excess of sodium, magnesium and hydrogen (acidity) zeolites in the hardpan is significant and also explains the low permeability of poor areas in this field.

* On this basis each base is directly comparable with another or with hydrogen in the proportion by weight at which they are capable of replacing each other.

TABLE I

of Soil Solution When the Soil Contains 20 Per Cent Moisture—Results Given in Parts per Million Soil Solution

Sample Depth	Soluble Solids	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Sulphate SO_4	Chlorine Cl	Remarks
0–1	4652	144	185	595	510	102	1066	Good drainage
0–1	6389	260	412	1108	488	417	2424	"
0–1	4334	154	308	931	224	416	1417	"
0–1	8304	432	400	1170	843	484	2698	"
0–1	3089	240	272	700	143	105	634	Fair drainage
1–2	3518	276	269	1264	184	325	955	"
2–3	3688	285	294	1246	205	424	1060	"
0–1	4581	192	271	947	294	112	988	"
0–1	5392	404	204	952	68	2252	996	"
1–2	5060	316	188	908	64	2200	952	"
2–3	4428	212	156	888	52	1960	868	"
0–1	3276	148	92	760	52	1244	548	"
1–2	3944	212	124	824	60	1884	592	"
2–3	4052	168	120	912	188	1968	784	"
3–4	6732	108	68	2056	248	4164	1712	"
0–1	2448	64	12	524	92	316	420	Good drainage
1–2	1984	64	16	504	92	412	356	"
2–3	2164	44	8	572	60	1796	464	"
0–1	7361	158	211	1063	280	856	1284	Fair drainage
1–2	7961	256	348	1478	586	1712	2524	"
0–1	11513	640	676	1711	700	1185	4139	Poor drainage
0–1	10380	447	604	1791	640	1060	3180	"
0–1	10256	521	614	1736	642	1276	3064	"
0–1	5372	255	400	1010	400	746	1577	"
1–2	8043	389	619	1470	206	1702	2128	"
2–3	7983	409	598	1518	215	1689	2449	"
0–1	3541	173	187	600	263	105	591	Fair drainage
1–2	2930	135	108	811	144	169	487	"
2–3	3574	180	210	910	131	319	934	"
0–1	11003	724	723	846	143	1163	3470	Poor drainage
1–2	11812	794	699	1172	171	2674	3680	"
2–3	12824	691	587	2702	131	2582	4088	"
0–1	...	303	314	570	108	532	936	Fair drainage
1–2	3496	226	264	840	86	490	978	"
2–3	6700	459	517	1348	122	1503	1632	"
0–1	6480	527	172	516	524	1136	1140	Good drainage
0–1	127196	4460	137	30612	700	18376	55596	Poor drainage
1–2	73576	572	28	12660	956	5808	20524	"
2–3	34756	416	92	10344	780	5588	15940	"
0–1	11364	288	...	2604	92	1088	2048	Fair drainage
1–2	9652	152	328	2360	220	1652	2616	"
2–3	11840	188	200	2644	704	2940	3650	"

CALCIUM, MAGNESIUM, SODIUM, POTASSIUM, HYDROGEN IN REPLA

Field	Sample	Sample Depth	Drainage	Cane Growth	Reaction pH	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K
19B	1	0–1	Good	Good	7.8	.340	.158	.016	.048
17A	3	0–1	"	"	7.7	.212	.054	.063	.004
21A	9	0–1	"	"	8.0	.191	.071	.024	.023
21A	10	0–1	"	"	8.0	.272	.111	.073	.034
14	15a	0–1	Fair	"	8.0	.215	.092	.034	.016
14	15b	1–2	"	"	7.7	.202	.085	...	...
14	15c	2–3	"	"	7.5	.184	.082	.032	.004
26B	2	0–1	"	Fair	8.0	.537	.368	.066	.084
A	19a	0–1	"	Good	7.5	.153	.059	.030	.015
A	19b	1–2	"	"	5.8	.082	.038	.025	.016
A	19c	2–3	"	"	4.6	.070	.028	.024	.022
A	20a	0–1	"	"	7.3	.186	.077	.024	.017
A	20b	1–2	"	"	5.6	.097	.062	.027	.026
A	20c	2–3	"	"	5.3	.094	.067	.030	.009
A	20d	3–4	"	"	5.1	.140	.142	.051	.009
A	21a	0–1	Good	"	7.3	.233	.134	.010	.024
A	21b	1–2	"	"	7.3	.210	.106	.037	.021
A	21c	2–3	"	"	7.2	.199	.086	.035	.019
3D	4a	0–1	Fair	"	7.3	.235	.108	.035	.013
3D	4b	1–2	"	"	6.7	.191	.095	.023	.010
3D	5	0–1	Poor	Fair	7.5	.118	.082	.052	.004
3D	6	0–1	"	"	7.5	.209	.095	.017	.005
3D	7	0–1	"	"	7.3	.240	.093	.040	.006
11	11a	0–1	"	Poor	7.5	.199	.119	.035	.010
11	11b	1–2	"	"	6.1	.132	.084	.044	.007
11	11c	2–3	"	"	4.8	.147	.054	.031	.000
11	12a	0–1	Fair	Fair	7.7	.200	.116	.012	.042
11	12b	1–2	"	"	7.7	.201	.108	.035	.009
11	12c	2–3	"	"	7.5	.195	.109	.047	.007
11	13a	0–1	Poor	Poor	7.7	.198	.116	.077	.015
11	13b	1–2	"	"	6.5	.221	.056	.009	.006
11	13c	2–3	"	"	5.3	.176	.065	.049	.000
11	14a	0–1	Fair	Fair	7.3	.199	.102	.050	.021
11	14b	1–2	"	"	7.2	.195	.107	.040	.011
11	14c	2–3	"	"	6.0	.157	.108	.051	.008
11	18	0–1	Good	Good	8.0	.282	.115	.063	.043
C	16a	0–1	Poor	Poor	7.7	.319	.203	.290	.083
C	16b	1–2	"	"	7.8	.267	.150	.237	.014
C	16c	2–3	"	"	7.0	.247	.140	.288	.011
C	17	0–1	Fair	Fair	8.2	.326	.078	.103	.036
C	17	1–2	"	"	7.5	.266	.108	.131	.022
C	17	2–3	"	"	7.0	.162	.123	.211	.004

TABLE II

ABLE FORM AS PER CENT IN DRY SOILS AND AS PER CENT TOTAL REPLACEABLE BASES

Hydrogen H	Total Bases	Ratio: Calcium Ca	Ratio: Magnesium Mg	Ratio: Sodium Na	Ratio: Potassium K	Milliequivalent (M. E.) Basis: Calcium Ca	M. E.: Magnesium Mg	M. E.: Sodium Na	M. E.: Potassium K	M. E.: Hydrogen H
....	.592	57.5	26.7	7.8	8.1	16.9	13.0	2.0	1.2	...
....	.333	63.7	16.2	19.0	1.2	10.6	4.4	2.7	.1	...
....	.309	62.0	23.0	7.8	7.4	9.5	3.8	1.0	.6	...
....	.490	55.5	22.7	14.9	7.0	13.6	8.0	3.2	.5	...
....	.357	60.2	25.8	9.5	4.5	10.7	7.5	1.5	.4	...
....	...	....	....	...	...	10.1	7.0	...	...	...
....	.302	61.0	27.1	10.6	1.3	9.2	6.7	1.4	.1	...
....	1.075	51.8	34.2	6.2	7.8	27.7	30.2	2.8	2.1	...
....	.257	59.6	22.0	11.7	5.8	7.0	4.8	1.3	.4	...
.006	.161	50.9	23.6	15.5	9.9	4.1	3.1	1.1	.4	5.9
.005	.144	48.6	19.4	16.7	1.3	3.5	2.3	1.0	.5	5.0
....	.304	61.2	25.3	7.9	5.6	9.3	6.3	1.0	.4	...
.0058	.212	45.8	20.2	12.7	12.3	4.8	5.1	1.2	.6	5.7
.002	.200	47.0	33.4	15.0	4.6	4.7	5.5	1.3	.2	2.0
.005	.342	40.9	41.5	14.9	2.6	7.0	11.6	2.2	.2	5.0
....	.431	54.6	31.1	9.3	5.5	11.6	11.0	1.7	.6	...
....	.374	56.2	28.3	9.9	5.6	10.5	8.7	1.6	.5	...
....	.339	58.7	25.4	10.3	5.6	9.9	7.1	1.5	.5	...
....	.391	60.0	27.6	8.8	3.3	11.7	8.0	1.5	.3	...
....	.319	60.0	30.0	7.2	3.0	9.5	7.8	1.0	.2	...
....	.286	51.9	28.7	18.2	1.4	7.4	6.7	2.2	.1	...
....	.356	58.7	26.7	13.3	1.4	10.4	7.8	2.0	.1	...
....	.388	62.0	24.0	12.6	1.0	11.9	7.6	2.1	.1	...
....	.354	50.2	33.6	10.0	2.8	9.0	9.8	1.5	.2	...
.005	.267	49.5	31.5	16.5	2.6	6.6	6.9	1.0	.2	5.0
.0085	.238	61.8	22.7	13.0	2.5	7.3	4.4	1.3	.1	8.4
....	.409	51.1	28.4	10.3	10.3	10.4	9.5	1.8	1.1	...
....	.353	57.0	30.6	10.0	2.5	10.0	8.0	1.5	.2	...
....	.358	54.5	30.4	13.2	2.0	9.7	8.9	2.0	.2	...
....	.406	40.0	28.6	19.0	3.7	9.0	9.5	3.3	.4	...
.006	.362	63.0	15.9	19.6	1.7	11.0	4.6	3.0	.1	5.0
.0067	.299	58.8	21.7	16.4	3.0	8.7	5.3	2.1	.2	6.6
....	.381	52.3	20.8	15.5	5.5	9.9	8.4	2.5	.5	...
....	.355	55.2	30.3	11.3	3.1	9.7	8.8	1.7	.3	...
....	.324	48.5	33.4	15.8	2.4	7.8	8.0	2.2	.2	...
....	.533	53.0	27.2	11.8	8.1	14.1	11.0	2.7	1.1	...
....	.895	35.6	22.6	32.6	9.2	15.9	16.6	12.5	2.1	...
....	.608	40.0	22.4	35.4	2.1	13.3	12.3	10.3	.3	...
....	.686	36.0	20.4	42.0	1.6	12.3	11.5	12.5	.3	...
....	.543	60.0	14.3	19.0	6.7	16.3	6.4	4.4	.9	...
....	.527	50.4	20.5	24.8	4.2	13.8	8.9	5.6	.6	...
....	.500	32.4	24.6	42.2	0.8	8.1	10.1	9.1	.1	...

An installation of tile drains had just been made in Field 3D a few months prior to the sampling. The crop was about six months old at this time. Samples of soil and subsoil were taken near one of the drain wells where cane was growing well and drainage had noticeably improved, as compared with the rest of the field. Three other samples were taken in areas which had not yet shown an improvement in drainage. The soils from the three latter areas were in poor mechanical condition and drainage was poor, all of which was reflected in a retarded cane growth. It may be seen that the principal abnormality in these samples is in the notably higher zeolite sodium in the poorly drained soils. This fact is undoubtedly associated with the soil properties above mentioned. On the other hand, the zeolite sodium has been materially reduced where the drainage has been improved, with a corresponding improvement in cane growth and soil texture. This field should be quite rapidly reclaimed on account of the high content of zeolite calcium.

Previous to 1920, Field 11 had given some trouble on account of a high water table. Tile drains were therefore installed for the purpose of lowering this table in order that the cane could be more effectively ripened. This was one of the original tile drain installations in the Islands and it was due to the success here that additional installations were made in Fields 3D and C. At the time the soil samples were taken (1927), the third ratoon crop was just starting and there were several areas in the field where the stand was very poor, and still others where there was no stand at all and replanting was necessary. The soil texture was notably heavier in the poor areas, and in some cases considerable salt efflorescence was visible. In the good areas, especially in the line directly over the tile, there was an excellent stand of cane and drainage was well regulated by a better mechanical condition of the soil. Two poor areas and two good areas were sampled. Sample 11 was taken from an area where the stand was poor and sample 13 where

Fig. 1. This figure shows the effect of salt accumulation on soil and cane growth in Field C.

there was practically no stand at all. The first, second and third foot were sampled separately. There is remarkably little difference in the zeolite base content of these samples, but a notable difference in soil reaction and zeolite hydrogen. On the basis of ratio of sodium to the total bases present, it is slightly higher in the poor areas which, along with the higher acidity, is probably related to the dispersion of the clay.

There has been from time to time considerable salt accumulation in Field C, but only in a small area, a low spot, has the accumulation become serious. In fact, in this area saline toxicity has exceeded the limit of tolerance of H 109 as shown in Fig. 1. Tile drains have been installed in this field as a step toward reclamation. As in Fields 3D and 11, where drainage had been improved, notably over the line of tile and near the drain wells, cane had already started to make a stand in this field. Soil samples were taken to a three-foot depth in one area where cane could not grow, and in a second area near the drain well where the soil had "opened up". There is a higher percentage of zeolite magnesium and sodium and also higher replacement capacity in the poorly drained toxic area, which is true also when the results are expressed on a milliequivalent basis. This is undoubtedly the cause of the low permeability in this field.

Comparison With Mainland Alkali Soil

A comparison of the data presented in Table I with the classification which Kelley has made of mainland soils is quite illuminating. It appears to be a significant characteristic of Ewa soils, which have been irrigated with artesian water, to be consistently higher in zeolite magnesium than mainland soils, and this introduces somewhat of a complication in using his classification. On the whole, though, the following deductions are reasonable. In Field A the samples taken from poor areas can be classed as intermediate saline types, while the third sample, except for its higher zeolite magnesium, can be classed as a good type. In Field 3D the sample from the good area can be classified as a good type, while the three samples from poor areas having a high zeolite sodium are placed in the intermediate class. In Field 11 all the samples are in the intermediate class, principally on account of a low calcium and high magnesium. The soil in Field C makes the nearest approach to a bad saline type, but still falls short of the minimum 50 per cent ratio for zeolite sodium in the bad soils examined by Kelley.

Salt Accumulation

Poorly drained irrigated soils are usually characterized by high saline accumulation, hence we find in Table I a wide variation in the salt content of the soil solution in this set of fields. In Field A the accumulation of sodium in the third and fourth foot is significant and probably a result of the puddled condition of this subsoil. The greater salt accumulation in the two poor areas, as compared with the good, is also a significant factor. The same is true in Field 3D where the higher salt content of the soil solution is associated with the poorly drained areas

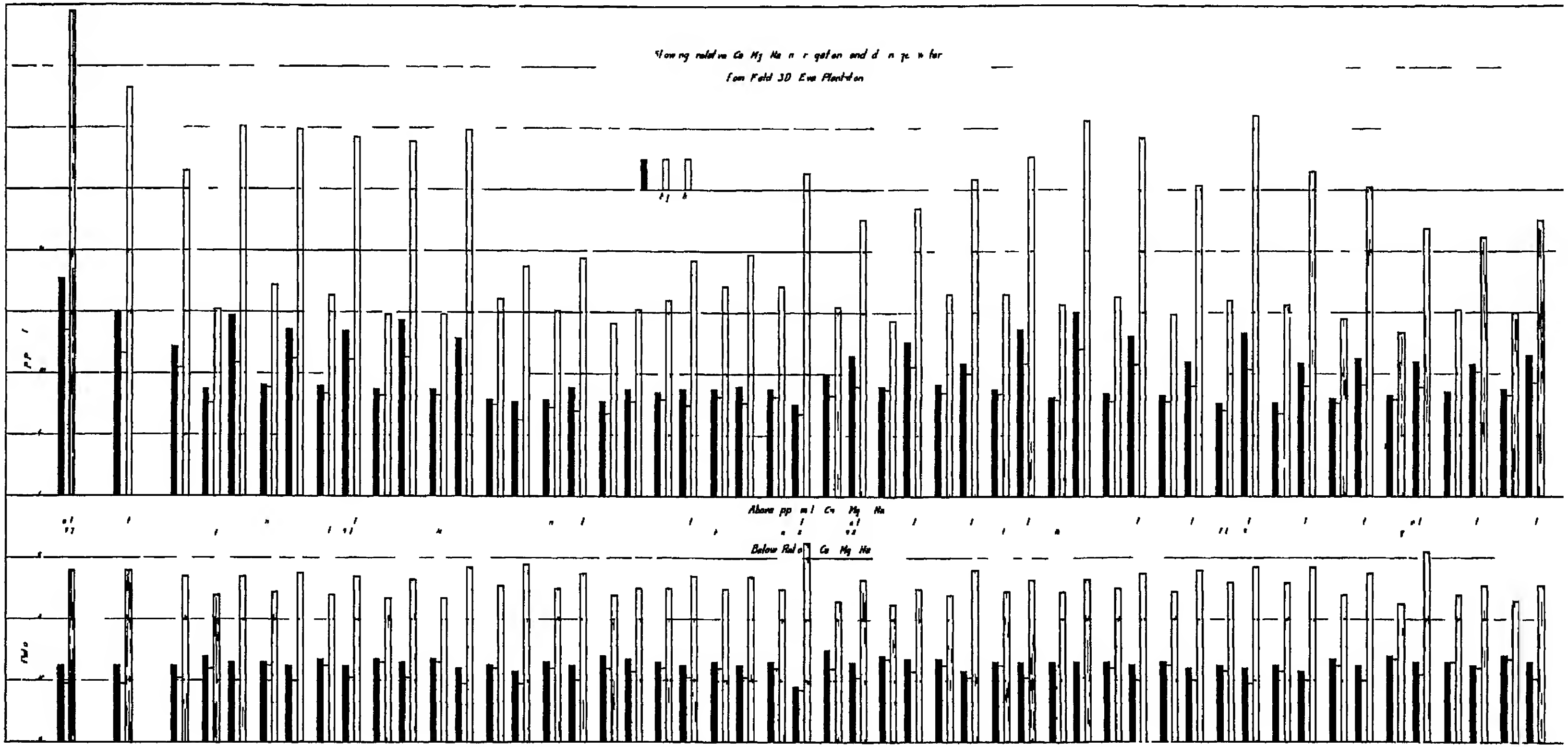

Fig 2 Showing relative Ca Mg and Na in irrigation and drainage waters from Field 3D

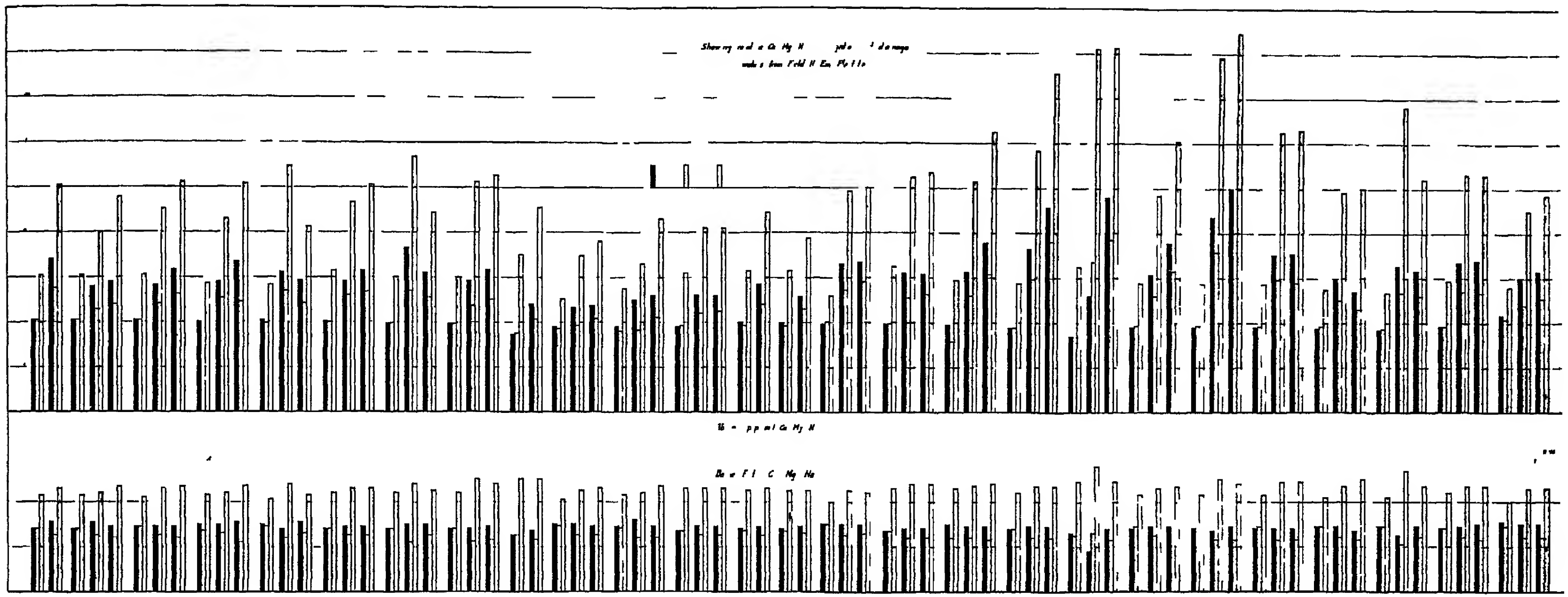

Fig 8 Showing relative Ca, Mg and Na in irrigation and drainage waters from Field 11.

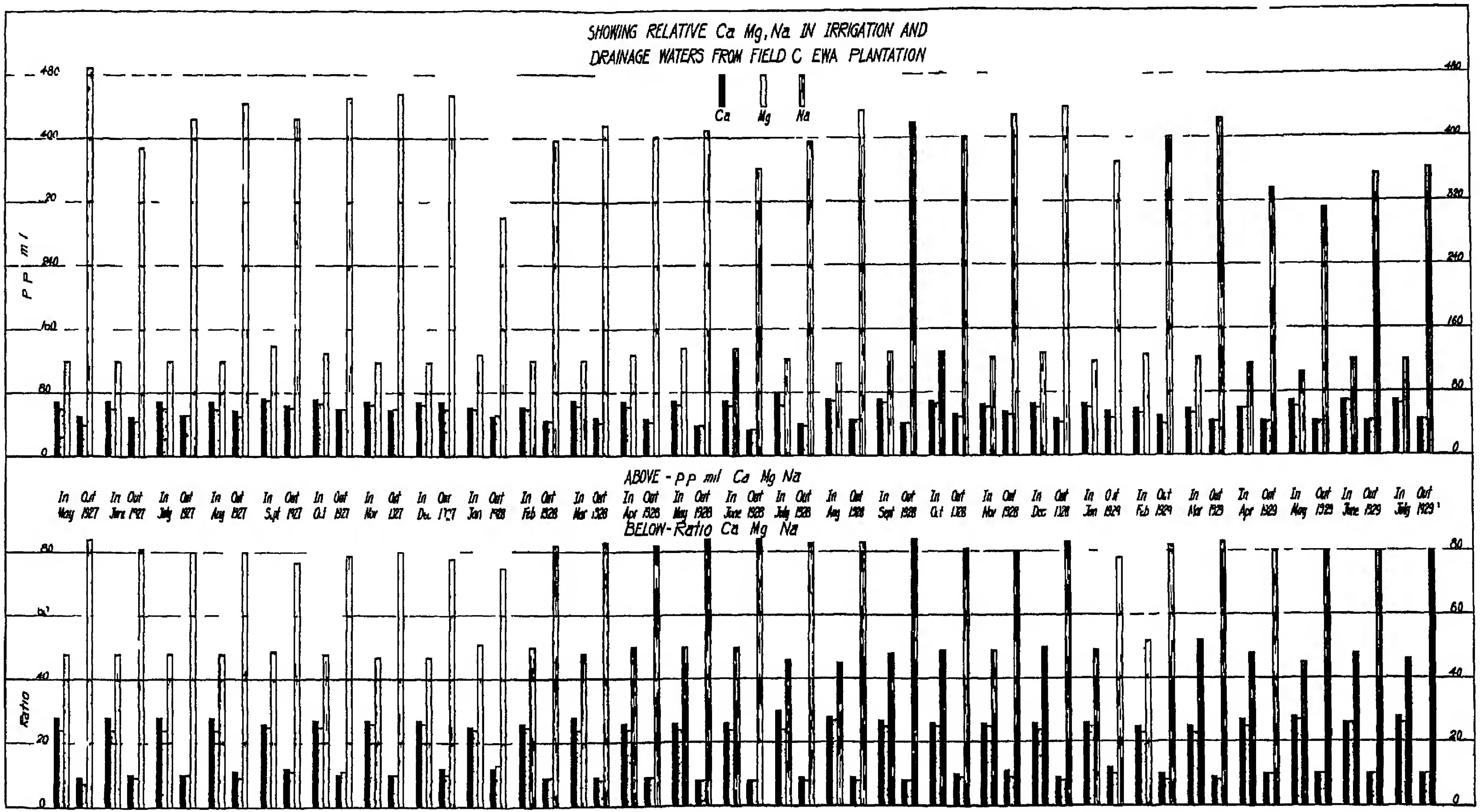

Fig 4 Showing relative Ca, Mg and Na in irrigation and drainage waters from Field C

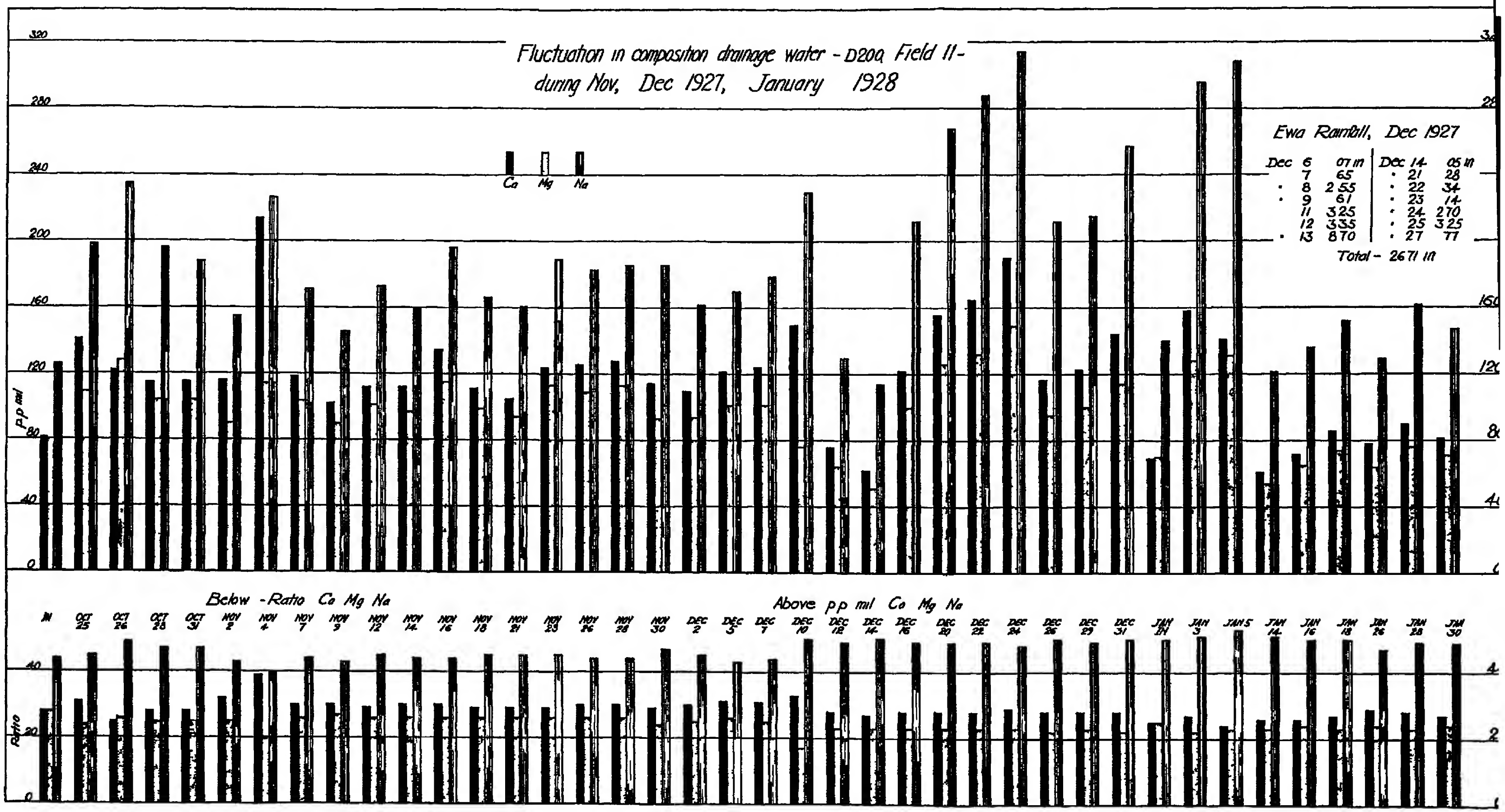

Fig 3. Showing variation in waters during November and December, 1928, and January, 1929

and retarded cane growth. Again, in Field 11 the same relation between salt accumulation, low permeability and cane growth run hand in hand. In the small section of Field C the soil solution has reached a concentration three times that of the Pacific Ocean water, and the soil is practically barren of vegetation. This has shown a remarkable reduction from 127,196 to 11,364 parts per million in the area where the soil is more permeable as a result of the tile drains and indicates the efficiency with which our Island saline soils can be reclaimed by tile drainage.

Tile Drainage

It is evident from the preceding data and discussion that none of the Ewa soils are in a chemical or physical state closely approaching a bad saline type. They are still quite high in replaceable calcium, while many of the bad alkali types on the mainland contain no calcium whatever as zeolite. On the other hand, a number of the Ewa soils are of intermediate types and abnormally high in zeolite magnesium. But since this is known to be a character of many Island soils which have never been irrigated with artesian water, we have no evidence in the preceding data that its presence in Ewa soils is due to the use of saline water. In order to study this question, as well as any other progressive changes taking place in the soil, the tile drained fields offered a possibility in the relation between the composition of the irrigation water being applied to the fields and as it was discharged from the drains, as compared with the composition and properties of the soil. So, at our request, the department of research and control at Ewa Plantation Company has been supplying us with composite water samples representing the monthly irrigation and drainage from Fields 11, 3D and C. Complete analyses of all these waters have been made, and the results are given in Tables III, IV, V, and shown graphically in Figs. 2, 3, 4 and 5. Only calcium, magnesium and sodium, the three bases which have the greatest influence upon the soil properties, are given graphically in terms of the ratio of each to the total of all three, and as parts per million. It is the ratio of one base to the others, rather than concentration, which governs fixation and exchange. In some cases, as noted in the tables, single water samples were analyzed, in addition to composites, in order to determine daily fluctuations, and for other reasons which will be mentioned later.

TABLE III

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field 3D, Ewa Plantation Company, May, 1927, to July, 1929

Date of Sample	Water	Chlorine	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
May, 1927	Out	844	2358	141	108	246	316	13	25	19	56
June, 1927	Out	732	2164	119	93	199	266	9	25	19	56
July, 1927	Out	580	1604	97	84	144	212	4	25	21	54
Aug., 1927	In	422	1211	70	61	78	122	12	28	24	48
"	Out	702	1777	118	87	173	241	5	26	20	54
Sept., 1927	In	422	1230	73	71	79	138	6	26	25	49
"	Out	688	1730	109	89	165	239	3	25	20	55
Oct., 1927	In	428	1124	72	67	81	131	4	27	25	48
"	Out	666	1635	108	89	141	234	4	25	21	54
Nov., 1927	In	420	1155	70	66	75	119	5	27	26	47
"	Out	715	1721	115	91	148	231	5	26	21	53
Dec., 1927	In	420	1155	70	66	75	119	5	27	26	47
"	Out	612	1635	108	79	170	239	7	24	19	57
Jan., 1928	In	372	921	63	60	68	129	9	25	24	51
"	Out	364	1889	62	50	95	150	6	23	19	58
Feb., 1928	In	378	1000	63	58	73	121	9	26	24	50
"	Out	406	1081	71	56	108	155	8	25	20	55
Mar., 1928	In	359	1102	62	54	79	113	.	27	23	50
"	Out	394	1154	70	62	76	122		28	24	48

Date of Sample	Water	Chlorine	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
April, 1928	In	411	1076	68	63	81	128	5	26	24	50
"	Out	397	1079	70	59	92	154	4	25	21	54
May, 1928	In	393	1113	70	65	75	137	4	26	24	50
"	Out	400	1137	72	61	86	158	2	25	21	54
June, 1928	In	393	1113	70	65	75	137	4	26	24	50
"	Out	360	1003	60	54	76	211	..	18	17	65
July, 1928	In	418	1182	80	66	73	124	12	30	24	46
"	Out	545	1449	92	74	108	181	8	26	21	53
Aug., 1928	In	432	1201	72	70	77	115	6	28	27	45
"	Out	631	1714	101	85	125	188	7	27	23	50
Sept., 1928	In	425	1118	73	68	81	132	9	27	25	48
"	Out	581	1490	87	80	117	207	8	23	21	56
Oct., 1928	In	422	1199	70	67	81	132	7	26	25	49
"	Out	588	1644	109	87	122	221	6	26	21	53
Nov., 1928	In	400	996	65	63	74	125	9	26	25	49
"	Out	695	1706	120	96	133	246	6	26	21	53
Dec., 1928	In	380	902	67	62	74	130	9	26	24	50
"	Out	620	1539	105	86	127	234	6	25	20	55
Jan., 1929	In	386	1041	66	62	75	119	6	26	25	49
"	Out	553	1371	88	72	110	203	6	24	20	56
Feb., 1929	In	361	966	61	56	73	128	6	25	23	52
"	Out	623	1440	107	83	131	247	6	24	19	57

Date of Sample	Water	Chlorine	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
Mar., 1929	In	347	920	61	54	68	125	10	25	23	52
"	Out	482	1301	87	72	102	212	13	23	20	57
April, 1929	In	387	1072	64	61	64	116	..	27	25	48
"	Out	524	1436	90	73	104	202	..	25	20	55
May, 1929	In	402	1059	66	63	73	107	..	28	27	45
"	Out	525	1367	88	71	98	175	..	26	22	52
June, 1929	In	403	1086	68	67	75	122		26	26	48
"	Out	515	1319	86	81	95	169	..	25	24	51

TABLE IV

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field 11, Ewa Plantation Company, May, 1927, to July, 1929

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
May, 1927	Out D100	720	2184	136	110	201	202	10	31	25	46
June, 1927	In	440	1524	79	77	84	.	6		..	
"	Out D100	582	1846	112	91	144	160	14	31	25	44
"	Out D200	632	2062	116	96	163	191	11	29	24	47
July, 1927	In	454	1420	92	82	87	122	5	29	29	42
"	Out D100	596	1814	113	96	145	181	7	29	25	46
"	Out D200	658	1990	127	105	155	204	4	29	24	47
Aug., 1927	In	450	1255	80	74	82	115	10	30	27	43
"	Out D100	626	1707	116	101	140	172	10	30	26	44
"	Out D200	696	1801	134	98	107	203	7	31	22	47

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
Sept., 1927	In	448	1258	82	79	97	113	6	30	29	41
"	Out D100	730	1867	125	108	163	219	8	28	24	48
"	Out D200	624	1688	117	97	133	165	9	31	26	43
Oct., 1927	In	458	1337	81	80	89	126	7	28	28	44
"	Out D100	670	1748	117	104	140	187	6	29	25	46
"	Out D200	708	1854	126	107	144	202	8	29	25	46
Oct. 25, 1927	"	704	1785	141	109	142	198	5	31	24	45
Oct. 26, 1927	"	856	2145	122	128	181	235	6	25	26	49
Oct. 28, 1927	"	690	1770	115	104	135	196	6	28	25	47
Oct. 31, 1927	"	652	1649	115	104	125	188	4	28	25	47
Nov., 1927	In	470	1130	79	79	83	120	5	28	28	44
"	Out D100	845	1912	146	108	185	227	13	30	22	48
"	Out D200	709	1746	124	102	135	177	9	30	25	45
Nov. 2, 1927	Out D200	600	1486	116	90	111	155	12	32	25	43
Nov. 4, 1927	"	1240	2772	214	114	232	227	13	39	21	40
Nov. 7, 1927	"	680	1619	119	104	128	171	10	30	26	44
Nov. 9, 1927	"	580	1365	102	90	111	146	11	30	27	43
Nov. 12, 1927	"	675	1593	112	101	127	173	10	29	26	45
Nov. 14, 1927	"	630	1616	112	97	112	160	10	30	26	44
Nov. 16, 1927	"	675	1897	135	115	147	197	13	30	26	44
Nov. 18, 1927	"	645	1574	111	99	125	166	9	29	26	45
Nov. 21, 1927	"	615	1575	105	94	124	161	11	29	26	45
Nov. 23, 1927	"	735	1790	124	113	140	190	2	29	26	45
Nov. 26, 1927	"	725	1805	126	109	137	183	2	30	26	44
Nov. 28, 1927	"	740	1873	128	113	137	186	6	30	26	44
Nov. 30, 1927	"	675	1730	114	93	130	186	6	29	24	47
Dec., 1927	In	470	1130	79	79	83	120	5	28	28	44
"	Out D100	624	1721	117	95	205	205	8	28	22	50
"	Out D200	693	1814	127	100	168	211	6	29	23	48

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
Dec. 2, 1927	Out D200	602	1555	110	94	121	161	11	30	25	45
Dec. 5, 1927	"	658	1675	122	101	126	170	14	31	26	43
Dec. 7, 1927	"	666	1713	124	101	140	179	4	31	25	44
Dec. 10, 1927	"	824	2094	150	76	173	230	4	33	17	50
Dec. 12, 1927	"	400	1079	76	64	120	130	4	28	23	49
Dec. 14, 1927	"	316	890	62	51	126	114	5	27	23	50
Dec. 16, 1927	"	652	1752	122	100	180	212	2	28	23	49
Dec. 20, 1927	"	864	2184	155	126	207	267	4	28	23	49
Dec. 22, 1927	"	920	2367	165	132	217	288	4	28	23	49
Dec. 24, 1927	"	1048	2620	190	149	235	314	6	29	23	48
Dec. 26, 1927	"	630	1692	117	95	110	212	4	28	22	50
Dec. 29, 1927	"	672	1871	122	100	207	215	7	28	23	49
Dec. 31, 1927	"	768	2094	144	114	226	257	5	28	22	50
Jan., 1928	In	392	988	69	70	72	140	9	25	25	50
"	Out D200	533	1346	96	83	133	181	6	27	23	50
Jan. 3, 1928	"	892	2149	158	128	239	296	5	27	22	51
Jan. 5, 1928	"	924	2152	141	131	243	308	8	24	23	53
Jan. 14, 1928	"	308	892	61	54	78	121	6	26	23	51
Jan. 16, 1928	"	392	1068	72	65	90	136	5	26	24	50
Jan. 18, 1928	"	432	1290	96	74	106	152	5	27	23	50
Jan. 26, 1928	"	392	965	78	64	79	127	8	29	24	47
Jan. 28, 1928	"	476	1162	90	76	121	161	6	28	23	49
Jan. 30, 1928	"	448	1088	82	71	111	147	5	27	24	49
Feb., 1928	In	426	1098	76	74	81	101	12	30	29	41
"	Out D100	483	1229	93	77	129	139	12	30	25	45
"	Out D200	532	1348	95	83	115	152	9	29	25	46
Mar., 1928	In	426	1202	76	72	79	110	..	29	28	43
"	Out D100	478	1366	100	75	100	132	..	32	21	43
"	Out D200	576	1556	104	85	116	172	..	29	24	47

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
April, 1928	In	439	1187	76	77	80	124	7	27	27	46
"	Out D100	552	1450	104	88	112	164	5	29	25	46
"	Out D200	552	1462	104	90	112	164	4	29	25	46
May, 1928	In	425	1211	80	77	80	126	3	28	27	45
"	Out D200	588	1614	114	96	115	178	4	29	25	46
June, 1928	In	425	1211	80	77	80	126	3	28	27	45
"	Out D200	552	1488	103	92	99	155	7	29	26	45
Aug., 1928	In	450	1244	79	81	80	104	5	30	30	40
"	Out D100	705	1868	132	109	194	197	6	30	25	45
"	Out D200	769	1987	134	116	181	200	7	30	26	44
Sept., 1928	In	446	1219	79	79	84	130	7	27	27	46
"	Out D100	687	1746	124	102	164	209	9	28	24	48
"	Out D200	673	1752	123	105	165	214	7	28	24	48
Oct., 1928	In	453	1250	78	63	84	118	12	30	24	46
"	Out D100	666	1798	125	104	161	206	8	29	24	47
"	Out D200	790	2164	151	123	205	250	5	29	23	48
Nov., 1928	In	435	1128	75	75	79	115	10	28	28	44
"	Out D100	738	1927	146	110	200	233	8	29	24	47
"	Out D200	960	2522	183	152	249	302	9	29	24	47
Dec., 1928	In	390	1016	68	67	76	130	6	26	25	49
"	Out D100	970	2370	104	154	276	324	5	18	26	56
"	Out D200	1010	2505	192	154	256	325	8	28	23	49
Jan., 1929	In	425	1185	76	77	81	115	11	28	29	43
"	Out D100	634	1686	123	104	168	194	7	29	25	46
"	Out D200	797	2085	151	126	192	242	6	29	24	47

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
Feb., 1929	In	425	1185	76	77	81	115	11	28	29	43
"	Out D100	964	2310	174	148	269	317	4	27	23	50
"	Out D200	1063	2565	200	160	270	338	5	29	23	48
Mar., 1929	In	425	1185	76	77	81	115	11	28	29	43
"	Out D100	723	1978	141	119	194	250	8	28	23	49
"	Out D200	716	1969	142	116	180	252	8	28	23	49
April, 1929	In	423	1200	75	77	76	110		29	29	42
"	Out D100	635	1707	120	100	139	197		29	24	47
"	Out D200	591	1590	108	92	126	200		27	23	50
May, 1929	In	424	1171	76	77	74	107		29	29	42
"	Out D100	719	1823	131	107	165	273		25	21	54
"	Out D200	683	1808	127	104	141	209		29	24	47
June, 1929	In	432	1196	77	77	72	118		28	28	44
"	Out D100	714	1846	133	108	168	213		29	24	47
"	Out D200	727	1860	136	107	154	212		30	23	47

TABLE V

Showing Composition of Irrigation Water (In) and Drainage Water (Out)

Field C, Ewa Plantation Company, May, 1927, to July, 1929

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
May, 1927	Out	790	1840	50	33	205	488	9	9	7	84
June, 1927	Out	672	1614	50	44	143	387	9	10	9	81
July, 1927	Out	714	1676	54	53	138	425	3	10	10	80
Aug, 1927	In	422	1211	70	61	78	122	13	28	24	48
"	Out	778	1856	58	52	151	445	4	11	9	80
Sept, 1927	In	442	1230	73	71	79	138	6	26	25	49
"	Out	786	1835	65	62	171	424	6	12	11	77
Oct, 1927	In	428	1124	72	67	81	131	4	27	25	48
"	Out	792	1825	59	60	168	451	5	10	11	79
Nov, 1927	In	420	1155	70	66	75	119	5	27	26	47
"	Out	810	1904	59	60	160	456	6	10	10	80
Dec., 1927	In	420	1155	70	66	75	119	5	27	26	47
"	Out	772	1823	68	60	176	455	12	12	10	78
Jan., 1928	In	372	921	63	60	67	129	9	25	24	51
"	Out	728	1048	50	53	102	302	6	12	13	75
Feb., 1928	In	378	1000	63	58	73	121	9	26	24	50
"	Out	658	1523	45	44	153	396	6	9	9	82
Mar., 1928	In	394	1154	70	62	76	122	16	28	24	48
"	Out	655	1500	48	42	143	417	15	9	8	83

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
April, 1928	In	411	1076	68	63	81	128	5	26	24	50
"	Out	652	1456	46	43	142	404	2	9	9	82
May, 1928	In	393	1113	70	65	75	137	4	26	24	50
"	Out	602	1383	38	39	132	411	7	8	8	84
June, 1928	In	393	1113	70	65	75	137	4	26	24	50
"	Out	580	1325	34	35	123	364	9	8	8	84
July, 1928	In	418	1182	80	66	73	124	12	30	24	46
"	Out	638	1440	44	38	135	393	8	9	8	83
July 23, 1928	Out	577	1253	34	33	116	356	14	8	7	85
July 26, 1928,	Out	570	1267	32	33	113	363	12	7	8	85
July 30, 1928	Out	588	1347	40	38	121	364	6	9	9	82
July 31, 1928	Out	567	1272	34	33	113	359	12	8	8	84
Aug., 1928	In	432	1201	72	70	77	115	6	28	27	45
"	Out	700	1592	46	44	149	436	8	9	8	83
Aug. 1, 1928	Out	744	1635	47	45	159	431	5	9	9	82
Aug. 4, 1928	Out	786	1801	57	53	166	454	4	10	9	81
Aug. 6, 1928	Out	744	1676	46	43	156	434	8	9	8	83
Aug. 8, 1928	Out	645	1418	37	38	130	395	10	8	8	84
Aug. 11, 1928	Out	680	1603	46	44	157	439	15	9	8	83
Aug. 13, 1928	Out	602	1351	35	35	122	382	11	8	8	84
Aug. 16, 1928	Out	574	1276	32	33	111					.
Aug. 18, 1928	Out	907	2061	64	55	232	578	11	9	8	83
Aug. 20, 1928	Out	645	1451	36	36	139	422	12	7	7	86
Aug. 23, 1928	Out	645	1547	57	49	116	362	10	12	10	78
Aug. 25, 1928	Out	829	1923	60	54	176	515	5	9	9	82
Aug. 28, 1928	Out	595	1362	38	39	122	381	4	8	8	84
Sept., 1928	In	425	1118	73	68	81	132	9	27	25	48
"	Out	680	1545	43	42	148	421	3	8	8	84

Date of Sample	Water	Chlorine Cl	Total Solids	Calcium Ca	Magnesium Mg	Sulphate SO_4	Sodium Na	Potassium K	Ratio Calcium Ca	Ratio Magnesium Mg	Ratio Sodium Na
Oct., 1928	In	422	1199	70	67	81	132	7	26	25	49
"	Out	680	1600	53	49	148	404	4	10	9	81
Nov., 1928	In	400	996	65	63	74	125	9	26	25	49
"	Out	704	1613	57	53	155	429	6	11	9	80
Dec., 1928	In	380	902	67	62	74	130	9	26	24	50
"	Out	670	1700	47	43	146	441	6	9	8	83
Jan., 1929	In	386	1041	66	62	75	119	6	26	25	49
"	Out	638	1490	55	48	135	368	4	12	10	78
Feb., 1929	In	361	966	61	56	73	128	6	25	23	52
"	Out	645	1440	48	42	137	403	4	10	8	82
Mar., 1929	In	347	920	60	54	68	125	10	25	23	52
"	Out	631	1445	44	43	131	423	10	9	8	83
April, 1929	In	387	1072	64	61	64	116	..	27	25	48
"	Out	584	1375	44	42	109	337	..	10	10	80
May, 1929	In	402	1050	66	63	73	107	.	28	27	45
"	Out	573	1327	43	42	101	312	.	10	10	80
June, 1929	In	403	1086	68	67	75	122	.	26	26	48
"	Out	594	1348	43	45	112	355	..	10	10	80

FIELD 11

The ratio of calcium in the irrigation water to that in the drainage is very consistent. While in some months there was a lower ratio of calcium to magnesium and sodium in the drainage water, on the whole the calcium was practically the same or slightly higher, which indicates little or no fixation of calcium from the irrigation water. A low calcium ratio would show that the calcium was being retained by the soil. With scarcely a single exception the magnesium ratio has been reduced in passing through the soil, showing a fixation of magnesium, and there should follow from this a progressive increase in zeolite magnesium in the soil. The relative sodium shows a consistently higher ratio in the drainage water Therefore, zeolite sodium is being steadily reduced, apparently by the magnesium rather than by the calcium. With the soil already high in zeolite magnesium, this can hardly be considered a desirable condition. It is rather significant that there was a slight increase in sodium ratio in December and January following 26 inches of rain in December.

Expressed as parts per million, there has been a wide variation in the calcium, magnesium and sodium content of the drainage water, while the irrigation water remained remarkably constant over the two-year period. In most cases, a greater amount of salt is being drained from D 200, which is the more fertile section of the field and indicates the benefit from salt removal.

In November, 1927, gypsum was applied to several ditches in the area drained by D 200. The effect of the gypsum is indicated in Figs. 3 and 5. These several samples were taken at short intervals following its application. In December, there was an unusually heavy rainfall, and from that time to harvest the concentration of bases in the drainage water was reduced. On the other hand, the daily changes fluctuated very greatly, as shown by the data in Table IV and Figs. 3 and 5.

In July, 1928, ground coral rock was applied at the rate of 9 tons per acre and the field plowed to a depth of 20 inches. From this period there was a steady increase in salt concentration of the drainage water, indicating that this treatment had served to release the salt in larger quantities and at a more rapid rate than previously. It should not be overlooked, however, that the deep plowing alone would have a somewhat similar effect in aiding leaching operations. Since February there has been some reduction from the maximum months of December, 1928, and January, 1929. It is significant that while the concentration of salt has been increased the ratio remained quite steady.

The gypsum, which was applied in the irrigation water from October 20 to 25, 1927, as shown in Fig. 3, has slightly increased the sodium ratio in the drainage.

During November, December and January, individual samples of water were analyzed, in addition to the composite, in order to determine the effect of the unusually heavy rainfall (non-saline water). The effect is of considerable interest. There were two periods of heavy rain, namely, 18.5 inches between December 8 and 13, and 6.1 inches between December 23 and 25. Therefore, less pump water was used during this month. Each period was followed by an increase in salt in

the drainage water and a higher sodium ratio for December and January. An occasional heavy rain appears to increase the sodium ratio in the drainage, but has little or no effect upon the calcium.

Field 3D

In Field 11, the tile drainage system had been in operation for five years previous to the start of these soil studies, while in Field 3D the field was being cropped for the first time after the installation of the tiles This is reflected in the high saline content of the drainage water during the first eight months The Ca·Mg:Na ratio is very similar to the drainage from Field 11 and shows that in this field, also, zeolite sodium is being reduced by base replacement On the other hand, unlike Field 11, and to better advantage, the calcium as well as the magnesium is being fixed by the zeolite.

An increase in salt content of the drainage started in again with the new crop, as noted by the months August to November, 1928. Also, the salt content was notably reduced by the rains of December, 1927.

In a comparison of the drainage waters from Fields 3D and 11, the better fixation of calcium in the former is significnat. In view of this, the average composition of the irrigation water applied to these two fields was calculated for the two-year period, and the results are given in the following table:

	Parts per Million			Ratio		
	Ca	Mg	Na	Ca	Mg	Na
Field 3D	68	63	125	27	24	49
Field 11	77	76	118	28	29	43

The pump water being used on Field 3D is, therefore, a slightly better water, having a higher ratio of calcium to magnesium, and this probably accounts for the more effective reclamation taking place in Field 3D. On the other hand, it is recognized that Field 3D was more recently tiled, which may be involved to a certain extent.

In expressing calcium: magnesium ratios by weight or concentration, the fact should not be overlooked that calcium has an atomic weight of 40.07, while that of magnesium is only 24.32. Therefore, the equivalent reaction or replacement value will be 40.07/24.32 or 1.65. That is, one part by weight of magnesium is equivalent to 1.65 parts by weight of calcium. This helps to explain, in part, the antagonism met in replacement operations when waters of nearly equal calcium-magnesium concentration are used. A water containing equal amounts of calcium and magnesium would in reality contain 1.65 as much magnesium on an equivalent basis.

Field C

Of the three fields under tile drainage, Field C offers an example of a very effective reclamation. As already stated, this field is the closest approach to a bad saline field and contains a high percentage of zeolite sodium, as well as an excessive salt accumulation. The drainage water analyses show a great reduction in

calcium and magnesium as the water leaches through the soil, with a corresponding increase in sodium both as ratio and as concentration in parts per million, which proves beyond question that the zeolite sodium is being steadily and effectively replaced by calcium and magnesium.

On July 14, 1928, calcium chloride was applied to the barren spot in this field at the rate of one ton per acre and then flooded. Drainage water analyses were made at each sampling during the rest of July and throughout August. There is some indication of improvement in the composition of the drainage water, but this is within experimental error and not conclusive. The excellent replacement which is already taking place in this field could hardly be improved upon except in rate. This could be accomplished by more frequent irrigation or flooding, especially if the area were contoured, to force the water to leach down through the bad area rather than through the more permeable area surrounding this barren spot.

Then again, one ton per acre of calcium chloride only furnished about 700 pounds calcium per acre, and the soil contains 26,000 pounds sodium per acre in the three feet of soil above the tiles.

In the preceding interpretations, and in the tables and graphs, no allowance was made for rainfall or variation in amount of water applied to the fields and the volume leaching out through the drains. The application of water varies, of course, with the rainfall and age of the cane. Thus far we have been concerned only with the relative concentration of bases in the ditch water and drainage. In the following tables, VI, VII, VIII, which were compiled and supplied by Mr. Bond, of Ewa Plantation Company, the rainfall, the relative monthly application of pump water and the monthly volume of drainage water for Fields 3D and 11 are given, together with rainfall.

From these data we have calculated the relative amounts of Ca, Mg and Na, which have been applied to the fields and removed in the drainage. These data are shown graphically in Fig. 6, both in pounds and ratio by weight.

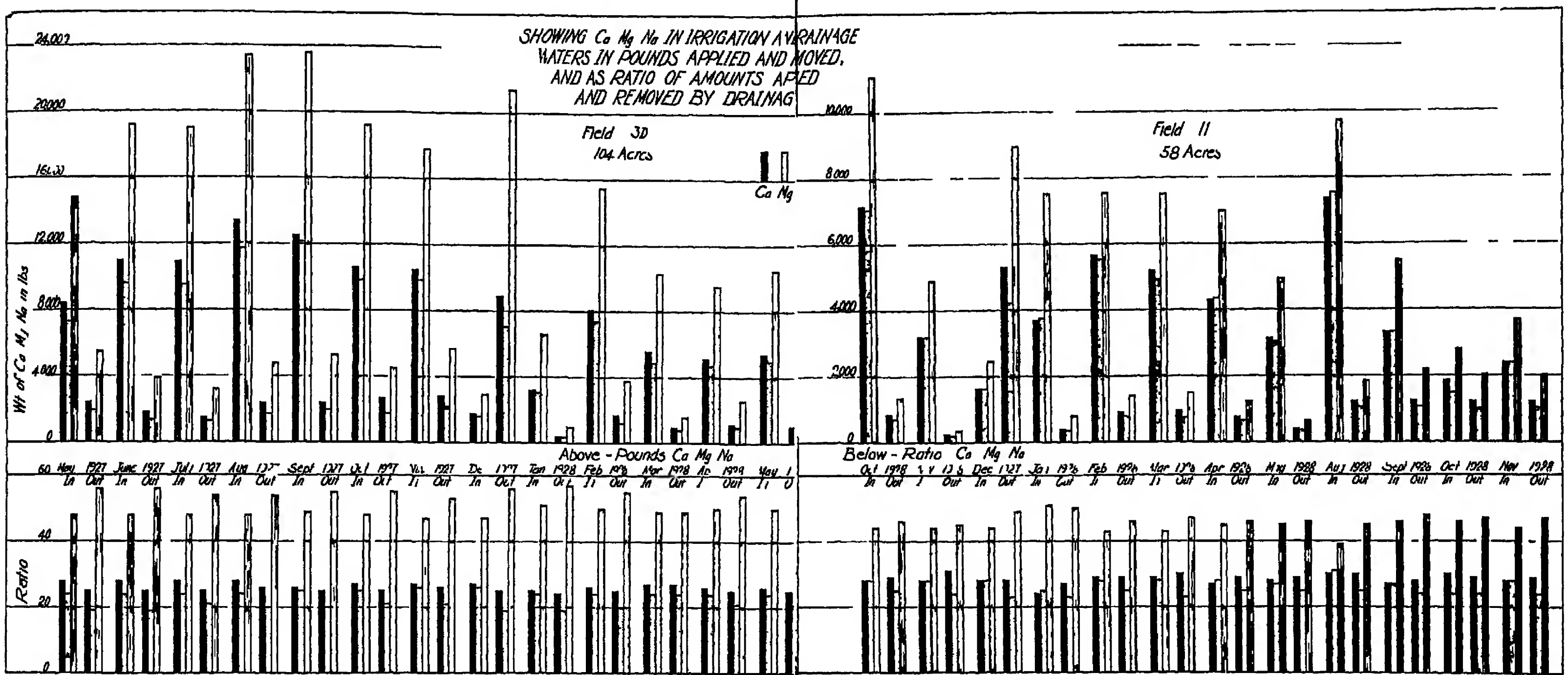

Fig 6 Showing pounds Ca, Mg and Na in irrigation and drainage waters from Fields 3D and 11

TABLE VI

Ewa Plantation Company

Field 3D; Crop 1928; Drainage Project; 104.00 Acres

	Millions of Gallons				Total Water Received	Millions of Gallons Discharge	Per Cent Discharge	Per Cent Discharge Without Rain
	Irrigation	Sprinkler*	Total	Rain				
1926								
Dec.	4.38	0.27	4.65	2.06	6.71	0.51	7.61	10.99
1927								
Jan.	5.99	0.27	6.26	5.14	11.40	0.98	8.60	15.66
Feb.	2.91	0.20	3.11	8.95	12.06	0.50	4.14	16.06
Mar.	7.97	0.14	8.11	13.95	22.06	1.13	5.12	13.93
April	5.74	0.14	5.88	6.24	12.12	0.92	7.61	15.69
May	14.24	0.34	14.58	7.74	22.32	2.10	9.41	14.41
June	18.65	0.37	19.02	0.79	19.81	1.78	8.98	9.36
July	18.16	0.61	18.77	0.93	19.70	1.83	9.27	9.73
Aug.	22.63	0.48	23.11	0.23	23.34	2.42	10.35	10.45
Sept.	20.14	0.48	20.62	2.68	23.30	2.68	11.48	12.97
Oct.	17.46	0.24	17.70	1.50	19.20	2.31	12.01	13.03
Nov.	17.74	0.23	17.97	5.51	23.48	2.99	12.73	16.62
Dec.	2.98	....	2.98	64.39	67.37	10.77	15.98	361.17
1928								
Jan.	6.15	....	6.15	0.90	7.05	0.77	10.98	12.60
Feb.	15.29	0.17	15.46	1.72	17.18	2.94	17.11	19.02
Mar.	10.78	0.17	10.95	2.17	13.12	1.56	11.85	14.20
April	8.97	....	8.97	4.52	13.49	2.04	15.14	22.77
May	9.15	0.10	9.25	....	9.25	1.78	19.29	19.29
June	....	....	....	2.06	2.06	0.64	30.81	....
		4.21	213.54	131.48	345.02	40.65	11.78	19.03

Field 3D; Crop 1930 1st; Drainage Project; 105.00 Acres

	Millions of Gallons				Total Water Received	Millions of Gallons Discharge	Per Cent Discharge	Per Cent Discharge Without Rain
	Irrigation	Sprinkler*	Total	Rain				
1928								
July	19.13	0.31	19.44	2.71	22.15	1.44	6.50	7.41
Aug.	15.12	0.34	15.46	0.37	15.83	0.65	10.44	10.69
Sept.	14.11	0.55	14.66	0.34	15.00	1.35	9.02	9.23
Oct.	15.84	0.72	16.56	2.59	19.15	1.83	9.55	11.54
Nov.	9.05	0.24	9.29	8.61	17.90	2.21	12.36	23.82
Dec.	8.02	0.24	8.26	2.11	10.37	1.75	16.86	21.16
1929								
Jan.	13.78	0.24	14.02	5.70	19.72	2.53	12.85	18.07
Feb.	8.69	....	8.69	13.14	21.83	2.83	12.97	32.59
Mar.	15.34	0.29	15.63	0.34	15.97	2.84	17.76	18.15
April	21.25	0.73	21.98	1.71	23.69	4.22	17.80	19.19
May	21.65	0.74	22.39	3.25	25.64	4.06	15.83	18.12
June	22.93	0.37	23.30	0.34	23.64	3.74	15.83	16.06
July	23.53	0.64	24.17	0.68	24.85	5.38	21.67	22.28

* Overhead Sprinkler System.

TABLE VII

Ewa Plantation Company

Field 11; Crop 1928 Short; Drainage Project; 58.30 Acres Under Drainage

	Millions of Gallons Irrigation	Rain	Total	Discharge in Millions of Gallons D–100	D–200	Total	Per Cent	Per Cent Discharge Without Rain
1927								
Feb.	....	2.25	2.25	....	0.03	0.03	1.44	....
Mar.	5.09	7.82	12.91	0.15	1.07	1.22	9.44	23.93
April	4.60	3.50	8.10	0.12	0.55	0.67	8.26	14.55
May	7.00	4.34	11.34	0.19	0.72	0.91	7.99	12.95
June	9.65	0.44	10.09	0.06	0.67	0.73	7.19	7.52
July	10.66	0.52	11.18	0.14	0.54	0.68	6 03	6.33
Aug.	11.25	0.13	11.38	0.15	0.73	0.88	7.76	7.84
Sept.	11.53	2.06	13.59	0.16	0.75	0.91	6.66	7.85
Oct.	10.60	0.78	11.38	0.08	0.73	0.81	7.18	7.71
Nov.	4.94	3.99	8.93	0.06	0.18	0.24	2.65	4.80
Dec.	2.49	33.83	36.32	1.58	3.59	5.17	14.23	207.90
1928								
Jan.	6.49	0.49	6.98	0.09	0.53	0.62	8.97	9.64
Feb.	9.00	0.49	9.49	0.28	0.89	1.17	12.27	12.93
Mar.	8.22	1.09	9.31	0.34	0.78	1.12	12.01	13.60
April	6.80	3.21	10.01	0.05	0.86	0.91	9.01	13.26
May	4.73	0.47	5.20	....	0.44	0.44	8.39	9.23
June	....	0.57	0.57	....	0.02	0.02	4.21	....
	113.05	65.98	179.03	3.45	13.08	16.53	9.22	14.60

Field 11; Crop 1930 Plant; Drainage Project; 61.70 Acres Under Drainage

	Millions of Gallons Irrigation	Rain	Total	Discharge in Millions of Gallons D–100	D–200	Total	Per Cent	Per Cent Discharge Without Rain
1928								
July	3.74	1.32	5.06	0.02	0.17	0.19	3.83	5.18
Aug.	11.24	0.35	11.59	0.24	0.87	1.11	9.62	9.92
Sept.	6.42	0.01	6.43	0.22	0.64	0.86	13.52	13.52
Oct.	5.10	1.79	6.89	0.43	0.82	1.25	18.09	24.45
Nov.	2.86	4.67	7.53	0.34	0.70	1.04	13.81	36.41
Dec.	3.88	1.46	5.34	0.16	0.69	0.85	15.90	21.87
1929								
Jan.	4.83	4.09	8.92	0.35	0.90	1.25	14.02	25.88
Feb.	2.41	5.53	7.94	0.21	1.19	1.40	17.68	58.23
Mar.	6.73	0.13	6.86	0.30	0.93	1.23	17.94	18.30
April	7.56	0.57	8.13	0.59	0.76	1.35	16.53	17.77
May	11.09	1.24	12.33	0.74	1.92	2.66	21.57	23.98
June	11.70	0.20	11.90	0.80	2.00	2.80	23.50	23.91
July	18.08	0.27	18.35	1.43	2.78	4.21	22.96	23.30

Few of the days estimated on account of the sticking of the meters.

TABLE VIII

Monthly Rainfall at Mill

Ewa Plantation Company

	Year 1927	Year 1928	Year 1929
January	....	0.31	2.44
February	....	0.54	3.30
March	....	0.69	0.08
April	2.21	2.03	0.34
May	2.74	0.30	1.14
June	0.28	0.36	0.12
July	0.33	0.79	0.16
August	0.08	0.21	....
September	1.30	0.03	....
October	0.49	1.09	....
November	2.52	2.79	....
		0.87	....

Fig. 6 does not cover the data in total. For Field 3D the period of May, 1927, to May, 1928, was selected, as this includes the heavy rainfall of December, 1927. For Field 11 the period of October, 1927, to November, 1928, was selected, which includes the heavy rainfall of December, 1927, and the period immediately following that at which the field was limed.

Field 3D: The heaviest applications of irrigation water were, of course, made during the summer months, and this is reflected in the large amounts of salt applied to the fields at this time. The effect of rainfall is quite significant. May, September, November, and especially December, 1927, all show a salt removal above the average and were high rainfall months, as shown in Table VI. The high removal of salt in December is reflected in a reduction in January. This is an example of the effect of pure water upon saline soils in that permeability will be subsequently retarded unless there is an excess of calcium remaining in the soil solution. In terms of the ratio of actual weight of bases in the drainage, and that in the irrigation water, the comparison is very similar to the concentration ratio, as shown in Fig. 2. Sodium ratio is greater in the drainage water, which is a desirable feature, while calcium and magnesium are being reduced or, in other words, fixed by the soil.

Field 11: As in Field 3D, the heavy rainfall of December is reflected in the large amount of bases removed in the drainage during this mon h. While the sodium is increased, there is no evidence that lime which was applied in June has changed the relative amount of magnesium leached out of the soil. Except for December, the amount of bases in drainage is higher and very constant. In fact, the lack of variation in total amount of calcium, magnesium and sodium leached from the soil following the application of lime, regardless of the amount of irrigation water applied, is remarkably consistent and indicates a better regulated movement of water. On the basis of weight ratio, the relation between calcium, magnesium and sodium is similar to the concentration ratio as given in Fig. 3. Calcium shows little or no reduction, and sodium is apparently being largely replaced by

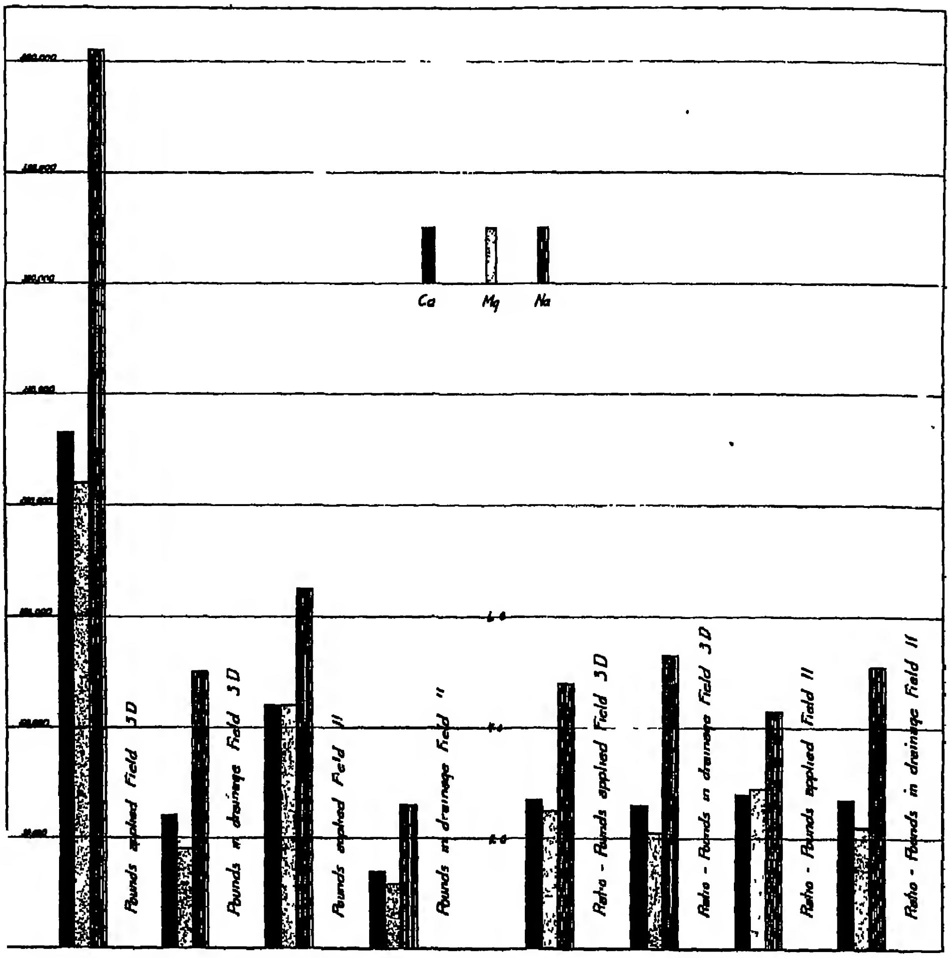

Fig. 7. Showing total Ca, Mg and Na applied and removed. Fields 3D and 11.

magnesium. There has been little or no change in ratio since liming, indicating that any magnesium which may be replaced by calcium is being precipitated in the lower soil horizons.

We have made no allowance in any of the preceding interpretations for the bases assimilated by the crop, but it is believed that these would be small in proportion to the amounts being applied in the water.

Fig. 7 shows the total amount of the three bases which have been applied to Fields 3D and 11 during the time of the investigation, and the amount removed during this time by the tile drains. As in our previous comparisons, the ratio between the bases is about the same. This figure shows again that either the water being used on Field 3D is more effective or that the tile installation is giving better permeability. It should be mentioned that both fields contain small areas which are not drained by the tiles, and the data in Tables VII and VIII, showing the amount of water applied, cover the field as a whole.

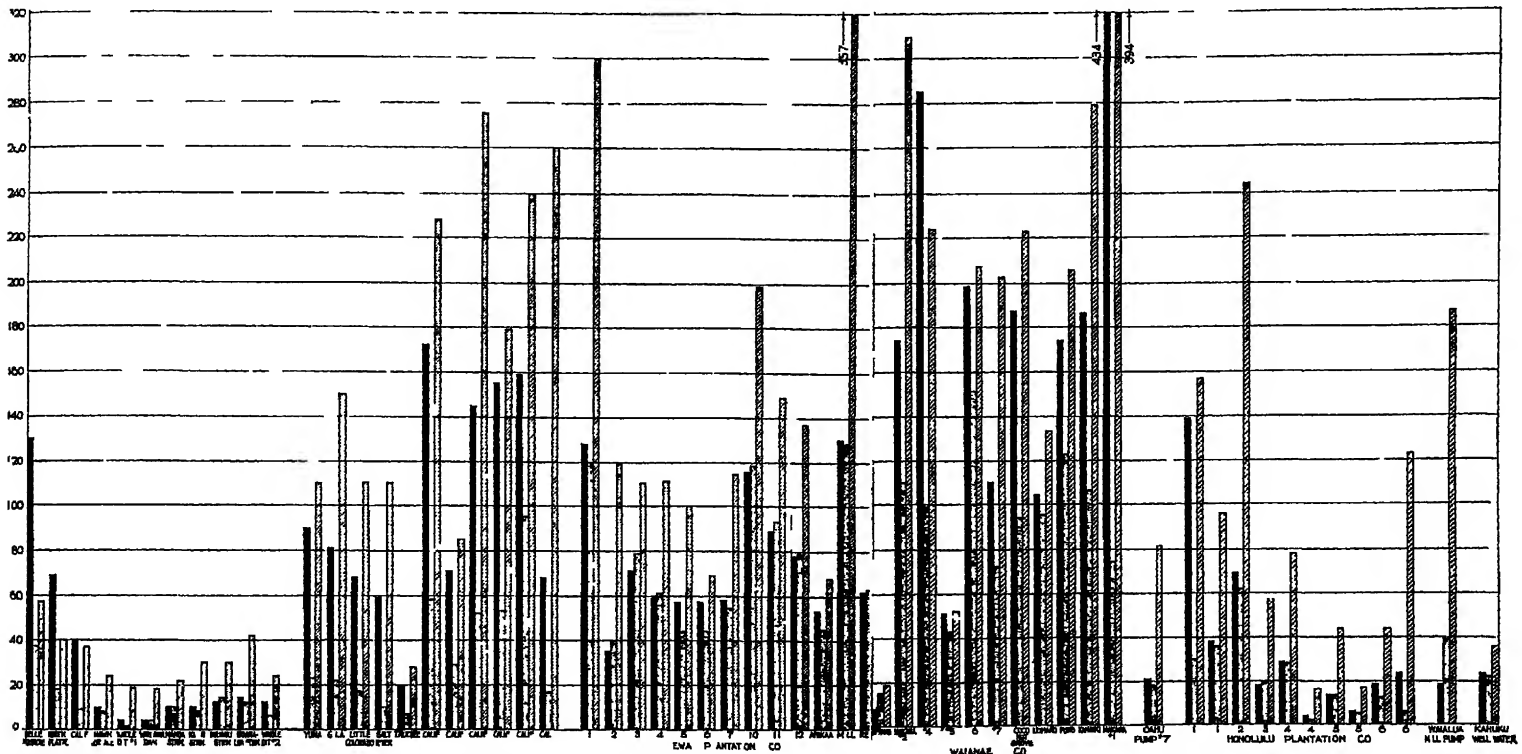

Fig 8 This figure compares the composition of Ewa irrigation waters with good and bad similar waters and some other waters from Oahu Parts per million Ca, Mg and Na Black—calcium Shaded—magnesium Cross lined—sodium

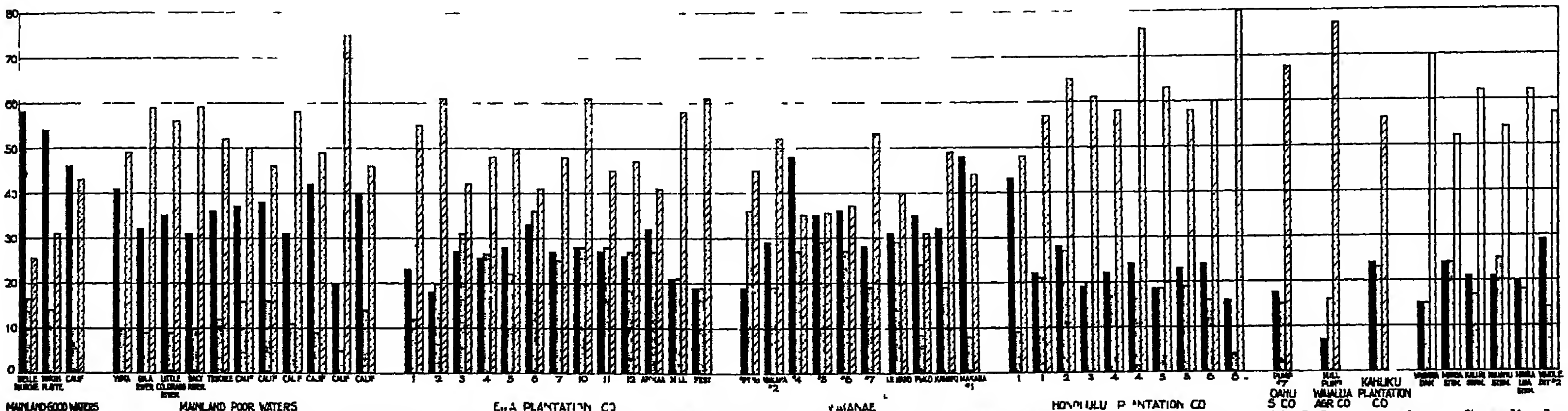

Fig. 9. This figure compares the composition of Ewa irrigation waters, as in Fig. 8, but in ter of ratio Ca : Mg : Na. Black—calcium. Shaded—magnesium. Cross-lined—sodium.

IRRIGATION WATER AT EWA

Considering as a whole the composition of the soil zeolites, the soil solution and the drainage waters from Ewa fields, and the fact that except for 20 inches per annum rainfall the plantation must depend entirely upon the artesian water supply, the present status of Ewa soils is quite good. Where injury to cane growth has occurred it appears to be due to salt accumulation rather than any chemical changes, to date, in the soil character. Where the soils are sufficiently permeable to permit a reasonable rate of water movement there has been little or no saline accumulation and, coincidently little or no injury to cane growth or soil properties. As we have already pointed out, Ewa soils are abnormally high in zeolite magnesium and the relative magnesium content of the irrigation and drainage waters indicates that the magnesium zeolite is progressively increasing. These data, however, do not offer final proof as certain of the magnesium salts are quite unstable and may be precipitating in the soil in some form other than the zeolite. Our data indicate that in Fields 11 and 3D a near equilibrium has been reached between the soil and irrigation water. In view of this, and in view of the lower zeolite sodium as compared with mainland saline types, we sought to compare Ewa irrigation waters, as well as several other Island waters, with those on the mainland.* These comparisons are given in Figs. 8, 9 and 10.

As already stated, the chemical changes in the soil zeolites are in most part a function of the ratio of Ca:Mg:Na in the irrigation water and the difference in the affinity of the zeolite molecule for the respective bases. Keeping this in mind, and comparing our Island waters with mainland waters, the data are quite illuminating. In Figs. 8 and 9 it will be noted that local waters are predominantly high sodium waters, and are not unlike the poor mainland waters in this respect. Even in our mountain streams, Waiahole ditch water and a Waianae spring, while the total salt content is very low, the sodium stands out as the predominant base. On the other hand, in not a single case does the magnesium exceed calcium in mainland waters, while in a number of the Ewa waters it not only exceeds calcium but in practically all samples is relatively higher than mainland waters. Attention is called to the waters on the extreme left of the figure, which have proven excellent for irrigation. They are predominantly high calcium waters. With the exception of several Waianae waters, no other similar types were found among this set of samples, which is fairly representative of the island of Oahu.

The analyses calculated to Ca:Mg:Na ratio are shown graphically in Fig. 9. Referring again to the good mainland waters at the left of the graph, it is significant that the Belle Fourche and North Platte irrigation projects have been remarkably free of alkali troubles. In fact, these two projects, out of the many installed by the U. S. Reclamation Service, stand out prominently for their permeable soils and absence of saline accumulations. This is due to the high ratio of

* Some of these Island waters were analyzed by the writer and other data were taken from the Experiment Station files. The data on California water were taken from some of W. P. Kelley's bulletins. The data on Arizona waters from the Salt River Valley were kindly supplied by P. S. Burgess. The data on other western waters were taken from publications of C. S. Scofield, U. S. Department of Agriculture.

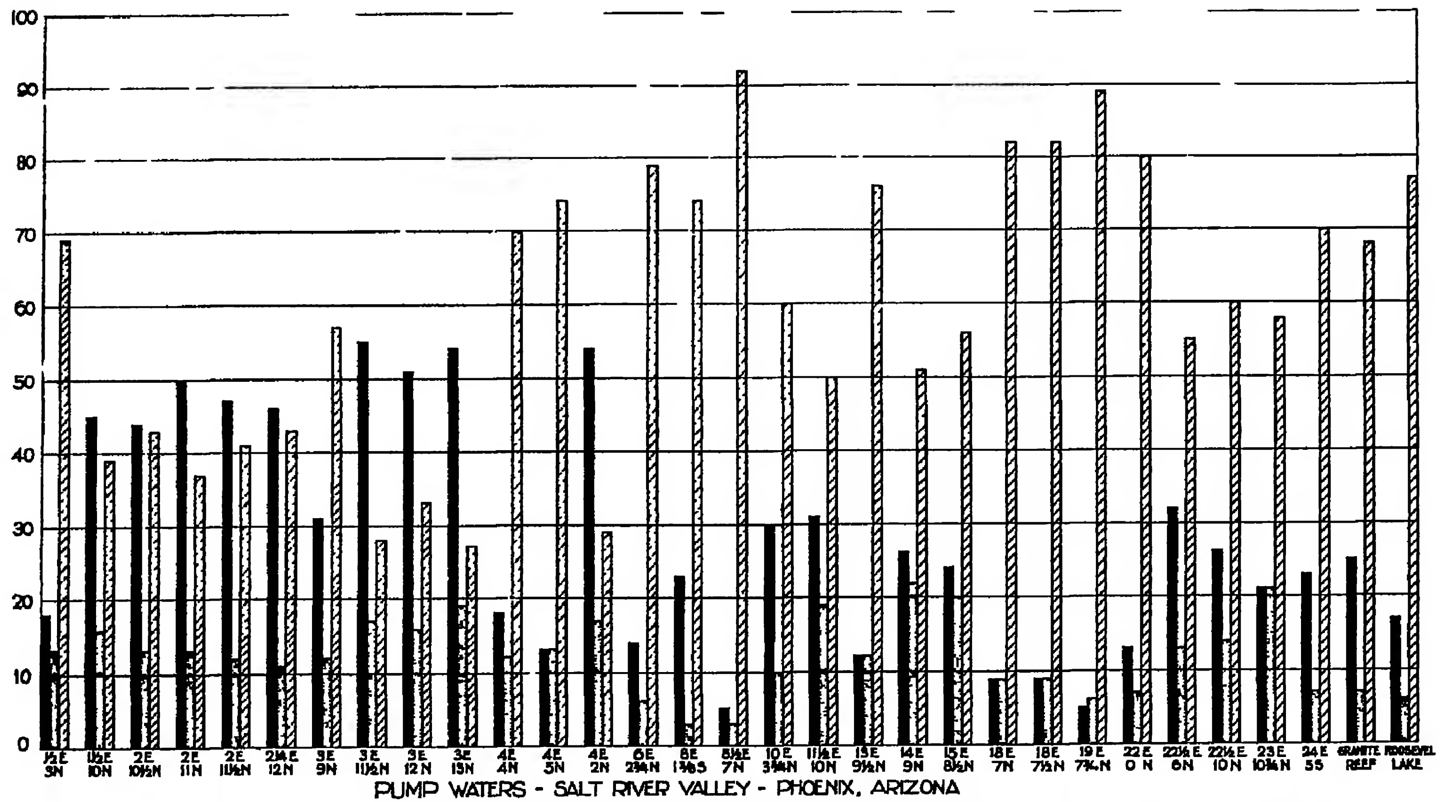

Fig. 10. This figure shows Ca : Mg : Na ratio in pump waters from Arizona. Black—calcium. Shaded—magnesium. Cross lined—sodium.

calcium in the water. In Fig. 10 some waters from the Salt River Valley in Arizona are shown. A number of these are high-calcium waters, and it is significant that in every case these waters represent sections of the valley which have never been troubled with alkali and, vice versa, the high sodium waters are from sections of the valley where soil troubles have been acute.

Ewa waters have a considerably lower calcium ratio and a higher magnesium ratio than poor mainland waters, while the sodium is about the same. Waianae waters are higher calcium waters, while Honolulu Plantation Company waters are more deficient in calcium than those at Ewa.

We are led to believe from this that since local waters are like poor mainland wa ers, high in sodium, and our calcium lower than poor mainland waters, the magnesium has been the prime factor in retarding or limiting the fixation of sodium. Furthermore, there is much which leads us to doubt that sodium fixation will ever reach serious proportions at Ewa or any Island soils irrigated with similar waters. In addition to the chemical data which have been presented, other conditions point to the same conclusion. We lack the wide climatic fluctuation of the arid and semi-arid west, namely, a rainy season followed by a hot, dry season during which there is usually very little vegetative growth to shade the soil. There will follow from these conditions an increase in salt content of the surface soil by capillarity and evaporation. Along with the absence of actively growing plants there is an absence of carbon dioxide secretion by roots which, in the form of bicarbonate, would tend to offset injurious effects of alkali. Our cane lands are under continuous cultivation, shaded most of the time and continuously irrigated. Then, too, our humidity is always high. Millar (6) has shown that when no vegetation was present in the field a considerable concentration of salts was noted in the surface one-fourth inch of soil during periods of drought. When the soil supported a growth of vegetation the tendency of salts to accumulate at the surface was largely prevented. A similar condition has been noted by the writer on Island soils (1).

In reclaiming alkali soils an effort is usually made to get alfalfa, an alkali-resistant crop, established as early as possible because the carbon dioxide root secretion, acting as bicarbonate, works for rapidly active and favorably reactive processes, largely as a solvent for calcium. A continuously growing crop is therefore recognized as a means toward staving off acute saline toxicity. If the soil is left unshaded, thus permitting an increase in salines, the less soluble calcium and magnesium will be the first to pass out of solution with an accompanying increase in the undesirable sodium.

There is still another factor which may be involved in that our Island soils are highly basic, and any alkalinity which might be formed by hydrolysis would, in part, react with aluminum and iron.

So we feel safe in concluding that if any difficulties arise they will be due to excess fixation of magnesium rather than sodium.

Gedroiz (7) in his early work on soil zeolites called attention to the high magnesium content of some compact Russian soils, and this has also been noted by

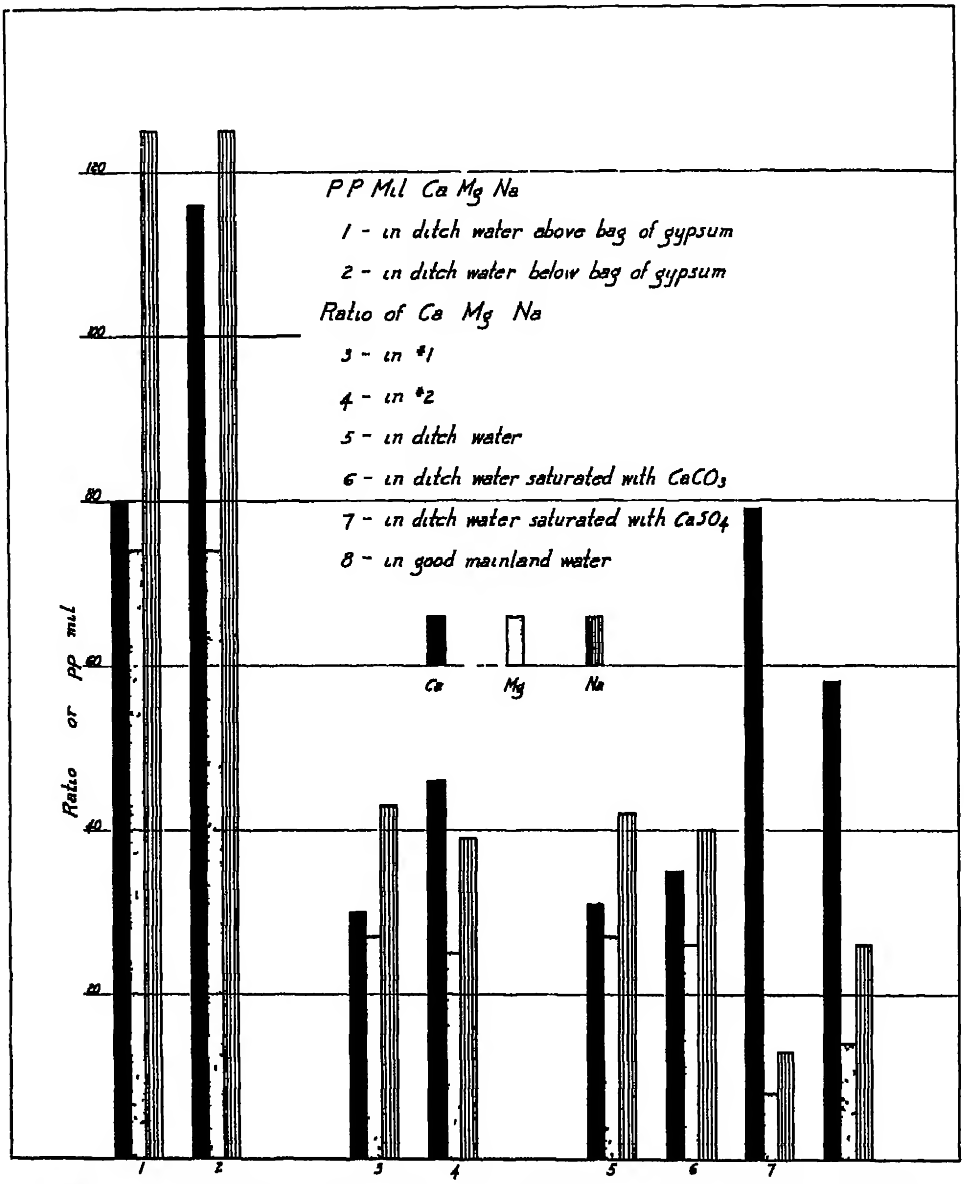

Fig. 11. Showing ratio of Ca : Mg : Na in waters treated with $CaCO_3$ and $CaSO_4$.

Kelley. Page and Williams (8) in England, and Hissink* in Holland, have also noted similar effects from excess magnesium fixation in soils which had been flooded by sea water. Hance (9) found high zeolite magnesium in Maui soils, and he experimentally demonstrated its effect upon soil properties. Gedroiz treated different samples of the same soil with the chlorides of sodium, potassium, magnesium and calcium, obtaining thereby a sodium-clay, a potassium-clay, a magnesium-clay and a calcium-clay. The sodium-clay showed the greatest dispersion; the potassium and magnesium clays similar dispersion but less pronounced, while the calcium-clay was well flocculated. The tendency of clay to remain in a dispersed deflocculated condition is closely associated with the liability of the respective ions to hydrolysis and, as we have already mentioned, this relative tendency between bases is in the order Na>K>Mg>Ca. It is thus evident that to permit an increase in zeolite magnesium, while not so disastrous as sodium, will work for an undesirable dispersed clay in the soil. The result will be a material reduction in permeability, aeration and development of other conditions characteristic of a soil of low fertility.

Corrective Measures

Knowing the properties of soil zeolites, such as their degree of hydrolysis, effect upon the mechanical condition of the clay and the respective affinity of the zeolite complex for the several common soil bases, it is easy to understand the commanding position which lime holds in the permanency of fertile soils. The proper procedure, therefore, either for preventing magnesium accumulation in Island soils or to reduce the zeolite magnesium in the fields where excessive fixation has taken place, is to use lime in some form.

Increasing the calcium ratio in the irrigation water by means of such materials as gypsum or calcium chloride offers a number of advantages and will reduce fixation and give replacement of both magnesium and sodium. Some experiments along this line were tried both in the laboratory and in the field.

We first conducted several experiments to determine the solubility of carbonate and sulphate of lime in the irrigation water being used in Field 11. This was determined by two methods, as follows: An excess of each was added to two separate bottles each containing two litres of water. The whole was shaken several times a day for one week, then filtered, and calcium, magnesium and sodium determined. As a second experiment, carbonate of lime and gypsum were added and mixed with a column of silica sand and the irrigation water allowed to percolate slowly through the sand. Calcium, magnesium and sodium were determined in this percolate. The solubility by both methods agreed very closely and the data are shown graphically in Fig. 11 as ratio Ca:Mg:Na (6 and 7) as compared with the same water before treatment (5) and a good mainland water (8). It is evident from this that this water may be converted to one of excellent quality by the use of gypsum. To try this out on a field scale, a bag of gypsum, with the side of the bag slit open, was placed in the ditch in such a manner that it was slowly dissolved by the irrigation water, and this treatment continued from October 20 to

* Cited by Page and Williams.

Fig. 12. Showing mechanical state of adobe clay where no coral is present.

Fig. 13. Showing the effect of coral rock on the mechanical condition of adobe clay.

27, 1927. The comparative analyses of the water taken from the ditch above the gypsum and 25 to 50 feet below is shown in Fig. 11 as parts per million (1 and 2), and as ratio (3 and 4). The composition of the drainage water from this section of the field is shown in Fig. 5 The amount of calcium dissolved by the water in passing over the bag of gypsum is far below saturation, but in spite of this there is some evidence of improvement in the composition of the drainage water, all of which shows that increasing the ratio Ca:Mg and Na will effectively control fixation of the other two bases.

As a practical procedure there are certain limitations to such an apparently simple method. Our fields are not uniformly poorly drained. There are scattered areas of widely varying permeability, and an application of calcium in the irrigation water would make less penetration in the areas where it is most needed, being too rapidly drained through the permeable areas. Where such wide variations in soil permeability exist in a field, limestone appears the more feasible procedure.

The heavy black clay which characterizes most of the poorly drained fields at Ewa occurs quite extensively in the lower fields of this Island We, therefore, sought fields of this soil type which had, during their formation, become mixed with coral rock. Such an area was found in Field 34, a peninsular field at Oahu Sugar Company, and, as we anticipated, the coral had greatly changed the soil to a very friable, mechanical condition, as shown in Figs. 12 and 13. In the former, the heavy soil texture is indicated by the manner in which the soil had caked on drying, while in the latter, the same soil type, the soil is in a good mechanical condition as a result of the coral rock, which is evident in the illustration. Five samples of soil were taken from this field, all representing the same black clay type. Numbers 22 and 23 were taken from opposite sides of the road, 22 being from a coral rock area, and 23 from an area free from coral and badly puddled. Samples 24, 25 and 26 were taken from another section of the same field, 24 and 26 from coral areas, and 25 where no coral was present.

The analyses of these soils are given in Table IX The zeolite base content is greatly different in the good and bad areas and correlates with the soil texture. This field is in the peninsular section of Oahu Sugar Company and very close to sea level, and there is no question but that if the elevation were sufficiently high to permit good water movement, the zeolite sodium and magnesium would be still further reduced.

TABLE IX

SOILS FROM FIELD 34 OAHU SUGAR CO.

Composition of Soil Solution at 20 Per Cent Moisture Content, Expressed in Parts per Million Soil Solution

Field	Sample	Sample Depth	Soluble Solids	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Sulphate SO_4	Chlorine Cl
34	22	0–1	4772	416	128	832	124	832	312
34	23	0–1	6460	116	28	1816	208	1816	964
34	24	0–1	8948	560	220	1644	380	2772	680
34	25	0–1	4480	44	24	1192	112	732	824
34	26	0–1	5904	508	96	1088	188	1332	460

Replaceable Bases in Per Cent Dry Soil

Field	Sample	Sample Depth	Drainage	Reaction pH	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Total
34	22	0–1	Good	8 1	.706	.142	.021	.085	.954
34	23	0–1	Poor	8.0	.275	.158	.192	.035	.660
34	24	0–1	Good	8.0	.486	.235	.075	.146	.942
34	25	0–1	Poor	7.8	.243	.144	.260	.112	.759
34	26	0–1	Good	8.0	.616	.059	.084	.092	.841

Ratio of Bases to Total, Per Cent of Total

22	74.0	14.9	2.2	8.9
23	41.7	23.9	29.1	5.3
24	51.6	24.9	7.9	15.5
25	32.0	19.0	34.3	14.7
26	73.2	7.0	10.0	9.8

Replaceable Bases on Milliequivalent Basis (M. E.)

22	35.2	11.6	.9	2.2
23	13.7	12.9	8.3	.9
24	24.2	19.3	3.2	3.7
25	12.1	11.8	11.2	2.8
26	30.7	4.8	3.6	2.1

There is, in the above, a natural example of the effect of coral rock, calcium carbonate, upon the mechanical texture and permeability of this black clay type and, incidentally, upon the zeolite magnesium and sodium. This effect of coral rock upon permeability has been further demonstrated in laboratory experiments already published in the *Record* (10). Its effectiveness for the replacement of magnesium is shown in the following experiment:

Two kilograms of soil were placed in each of four large glass percolators. One was leached with distilled water until it became so dispersed and swollen that percolation was completely stopped. The second was leached with ten litres of the same artesian water being used in the field. The third was leached with artesian water after gypsum had been mixed with the surface layer of soil. The fourth was treated in the same manner except that ground coral rock was used instead of gypsum. The soils were then dried, ground and analyzed for zeolite calcium, magnesium, sodium and potassium. The results are given in the following table, together with the same soil, before treatment:

	Per Cent Calcium Ca	Per Cent Magnesium Mg	Per Cent Sodium Na	Per Cent Potassium K
Check—no treatment	.219	.116	.047	.013
Leached with distilled water	.212	.117	.051	.009
Leached with artesian water	.215	.169	.043	.014
Gypsum added to soil	.370	.103	.044	.016
Coral rock added to soil	.385	.076	.051	.014

It is evident that leaching with distilled water, the amount we were able to leach through the soil, had little effect upon the zeolite bases. The artesian water has greatly increased the zeolite magnesium, which confirms our field observations. The zeolite magnesium was considerably reduced by the gypsum, but much more effectively by the coral rock.

Field 11 was harvested in June, 1928, and, in view of the fact that the ratoon crop had "gone back" noticeably in the poorer drained areas, the field was plowed and replanted. Ground coral rock, at the rate of 9 tons per acre, was applied before plowing, leaving unlimed areas for comparison, and observation has indicated that there has been a noticeable increase in fertility and cane growth on some of the limed areas. A better permeability is also indicated in the composition of the drainage water beginning with August, 1928, and there is some improvement in the Ca:Mg:Na ratio. Hence, there is plenty of evidence that such Island adobe soil types will be greatly benefited by liming and *that by all means nitrate of lime is the most desirable form of nitrogen to apply to such fields.* It should be mentioned that Field 11 was plowed to a depth of 20 inches, and while we recognize that such a deep plowing would in itself improve the permeability of the soil in this field, we believe that it is in most part due to the lime application.

Breazeale (11) has shown that when calcium carbonate is present in the soil the calcium will react with the magnesium in irrigation water and then enter into base replacement reactions. He found that when calcium chloride and magnesium chloride were added in equivalent amounts to a soil containing both calcium and

magnesium zeolites, no base replacement took place. This is similar to the condition which we have noted in Field 11, except that on an equivalent basis the magnesium is greater than the calcium in the irrigation water. Breazeale has further shown that the calcium present in the soil as calcium carbonate, when dissolved in water that contains carbon dioxide, will replace magnesium from zeolite. This is in accord with our findings.

Calcium carbonate is soluble to 10 parts per million in pure water, will increase in solubility with increase in carbon dioxide content of the water, and may reach a solubility of 1000 parts per million as calcium bicarbonate. Sodium chloride or sodium sulphate, both of which are present in our artesian waters, notably increase the solubility of calcium carbonate. While most calcium salts are less soluble than magnesium salts, this is not true of the hydrate and carbonate. Calcium hydrate is soluble to about 1600 parts per million, while magnesium hydrate is only soluble to 8-10 parts. From this it is evident that calcium carbonate may not only effectively function in base replacement, but also function in precipitating magnesium as carbonate in the soil. The high magnesium present in our coral fields is probably there, in part, as the carbonate as well as the zeolite, and it is difficult to determine the latter in the presence of the former.

The chemical reaction known as base replacement is stimulated or retarded according to the rate or degree of ionization of the zeolite bases, and when ionization is stopped base replacement is no longer possible. For example, Breazeale (11) has shown that a 4 per cent solution of sodium chloride in a saturated solution of gypsum will completely stop replacement of sodium by calcium, if such a solution is used to leach the soil. A 2 per cent solution of potassium chloride will in like manner stop replacement of potassium by calcium. It is evident from this that in a complex salt solution, such as an irrigation water, equilibrium between soil solution and zeolites will continuously vary. If permeability is reduced and salt accumulation permitted, a rising concentration of undesirable bases, such as was found in Field C, for example, may completely stop ionization of the zeolite bases and no replacement will take place until permeability has been restored to the soil.

Soil Acidity in Poorly Drained Areas

In our discussion of the data in Table II we called attention to the high acidity which had developed in the subsoils of the poorly drained areas. These data, given in terms of pH and specific acidity, are given in the following tabulation:

REACTION AS pH

	Field 11		Field 11		Field A		
	Poor	Good	Poor	Good	Poor	Poor	Good
First foot	7.5	7.7	7.7	7.3	7.5	7.3	7.3
Second foot	6.1	7.7	6.5	7.2	5.8	5.6	7.3
Third foot	4.8	7.5	5.3	6.0	4.7	5.3	7.2
Fourth foot	...	...	...	...	...	5.1	...

REACTION AS SPECIFIC ACIDITY

First foot	0.32	0.19	0.19	0.50	0.32	0.50	0.50
Second foot	8.00	0.19	3.20	0.63	16.00	25.00	0.50
Third foot	160.00	0.32	50.00	10.00	250.00	50.00	0.63
Fourth foot	...	...	....	...	.....	80.00	...

This condition is directly a result of the highly dispersed clay in the soil and its accompanying effect upon soil permeability and aeration. The highly acid subsoils were found only in the poorly drained areas in which aeration has been sufficiently reduced as to injure cane growth. Cane roots *must* have air as well as nutrients in order to properly and effectively function. Likewise, the activities of beneficial organisms are acutely retarded by lack of aeration. In their place another and undesirable soil flora is created, namely, the anaerobic organisms, which create an extremely toxic environment in the root zone. One effect of an active anaerobic soil flora is the development of soil acidity, and this is unquestionably what has taken place in the poor spots in Fields 11 and A. The affinity of the soil zeolite for hydrogen, the acid ion, is so much greater than for the bases that it is rapidly absorbed by the zeolite in spite of the accumulated concentration of the bases calcium, magnesium and sodium in the soil solution. We believe that lime will, in addition to improving permeability, correct this acidity in the subsoils.

Following the harvest of the 1928 crop in Field 11, D. M. Weller, at the request of Mr. Alexander, made root counts in selected poorly drained and well-drained areas in this field. The roots growing in the kuakua and each eight inches of the soil horizon were separated and weighed. At the same time we made analyses of the soils from each horizon. These data were reported by Mr. Alexander in the 1928 Proceedings of the Association of Hawaiian Sugar Technologists, and on account of their significance are reproduced in the following tabulation:

SHOWING ZEOLITE BASES, REACTION AS pH AND WEIGHT OF ROOTS FROM SEVERAL SOIL HORIZONS FROM GOOD AND POOR SPOTS IN FIELD 11

	Calcium		Magnesium		Sodium		pH		Wt. of Roots	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
Kuakua	.256	.201	.116	.126	.016	.028	7.4	6.7	9.9	35.7
First 8 inches	.223	.204	.106	.114	.016	.073	7.9	7.1	157.6	102.0
Second 8 inches	.136	.151	.092	.086	.019	.018	7.4	6.6	40.4	3.9
Third 8 inches	...	.134	...	.088	...	.037	...	5.3	16.7	.2
Fourth 8 inches	.121	.115	.078	.088	.020	.018	5.3	4.7	2.8	.1
Fifth 8 inches	.135	.083	.088	.074	.020	...	5.7	4.8	.8	.01

These data are extremely significant and serve to emphasize the air requirements of the cane roots. In the poorly drained spot there are practically no roots below eight inches. Ninety-seven per cent of the roots are present in the kuakua and eight inches of surface soil. The improvement in permeability from the tile drains has increased root growth 60 per cent. At the same time there has been an improvement in the zeolite composition, namely, an increase in zeolite calcium and a reduction in zeolite hydrogen, magnesium and sodium, all of which will work progressively for better soil fertility.

Discussion

The results obtained in this investigation serve to establish a number of significant and important facts regarding the fertility of Ewa soils and can be applied to many other Island areas. None of the Ewa soils closely approach what we would term acute saline conditions. On the other hand, due to either poor drainage, soil texture, or high water table, there has been sufficient salt accumulation in some fields to reduce cane yields. It is significant in this connection that a recent survey of Ewa yields, by Das (12), covering a number of years, has shown that Lahaina failure at Ewa was definitely associated with certain soil types, notably the poorly drained. We have demonstrated the presence of high saline accumulations in such fields and it has been shown that even when Lahaina was at its worst, during the dry years, the cane made excellent growth after a heavy rain. Therefore, the low fertility of the poorly drained fields is not of recent recognition, and within late years has led to the installation of tile drains in several such fields.

The line of investigation which we have pursued has sought to augment our fundamental knowledge of the present condition of Ewa soils beyond a mere accumulation of salts and its physiological effect upon cane growth.

That fraction of clay which is referred to as a zeoli'e compound lies at the very foundation of most soil properties, both desirable and undesirable. In Ewa soils we find that the sodium present as zeolite, while above the average of a normal soil, is far short of the recognized serious proportion. That this is true, in spite of the fact that high sodium waters are used to irrigate and heavy applications of nitrate of soda have been made over an extensive period of years, is very significant. Only where drainage is very bad has there been any evidence of an increase in zeolite sodium, and this is being effectively reduced by drainage.

On the other hand, there are on this Island a number of scattered areas in which a heavy black clay type of soil exists. It has been found that the zeolite compounds present in this type are in large part, or in excess, combined with magnesium. The clay fraction of the soil when combined with an excess of magnesium will, like sodium, but to a lesser extent, exhibit a high degree of dispersion. In fact, there may even be an increase in the amount of clay in the soil, as shown by Gedroiz. He took a soil containing 39.9 per cent of clay, saturated it with sodium and thereby increased the clay to 59.8 per cent. Soils, then, containing an excess of sodium or magnesium zeolite, will usually be heavy clays and be composed physically of a high percentage of the clay fraction. The heavy clay, magnesium type, is present in a number of Ewa fields and it is characteristically difficult to drain. The irrigation water in use at Ewa, as compared to a wide variety of irrigation waters in use on the mainland, contains an abnormally high magnesium content in proportion to calcium. This high magnesium, together with the calcium, has, in most part, prevented an excessive fixation of sodium as zeolite in Ewa soils. On the other hand, this high magnesium present in the water has limited fixation of calcium, the fixation of which is highly essential in maintaining an optimum soil texture and a permanent soil fertility. At the same time, the magnesium zeolite has increased in some fields, notably where drainage is poor

The problem then resolves itself into a reduction of zeolite magnesium in the poorly drained fields and a prevention of any further accumulation.

We have made rather an exhaustive study of conditions in Fields 11, 3D and C where tile drains have been installed, and the evidence strongly indicates that while the tile drains effectively leach out the excess salt accumulation and lower the zeolite sodium, this practice probably will not reduce the magnesium unless supplemented by some form of calcium.

In areas where this black clay soil is located near coral fields, and along its border it has become merged with the coral soil, the highly dispersed state is entirely changed to one of an excellently flocculated soil. This fact, together with a number of laboratory studies which have been described, shows beyond question that this soil type, even at its worst, will be greatly improved in fertility by liming. Of course, the addition of gypsum or other soluble calcium salt to the irrigation water to increase the calcium ratio of the water, as has been shown, would prove another effective procedure. But most of the areas of this soil type on Oahu are in the makai lands where ground coral rock can be very economically obtained. The freight on gypsum, which must be imported, adds greatly to its cost.

We believe we have sufficient evidence to conclude that the fertility of poorly drained areas of this black clay type can be effectively improved by liming with ground coral rock and by using nitrate of lime to supply the nitrogen requirements of the crop.

Both as a matter of prevention, and as a step in the reclamation of lands already gone bad, a great deal of attention on the mainland is being centered on the composition of irrigation water. From a knowledge of the soluble bases and zeolite bases in the soil, and the composition of the irrigation water, it is possible to predict a great deal regarding the cultural possibilities of the land. In some ways, though, the mainland problems are more simple than ours. As a rule, in mainland soils magnesium rarely enters the absorption complex in sufficient quantities to influence its properties. Their problem is confined largely to calcium and sodium, namely, to prevent fixation of the latter or to effect its removal where fixation has become excessive. Zeolite sodium much more disastrously affects soil properties than magnesium but is, on the other hand, more easily replaced by calcium and therefore it is much simpler to prevent sodium fixation than that of magnesium. The fixing power of clay is so much lower for sodium than for calcium or magnesium that unless the former is greatly in excess of the two latter there is not much danger of the clay becoming saturated with sodium. On the other hand, the fixing power of clay for calcium and magnesium is so nearly equal that it becomes a much more difficult problem to control the fixation of magnesium, especially where our irrigation waters are already high in this base. It is not, however, an impossibility.

That the tile drains in Fields 3D and 11 have effectively reduced salt accumulation in these fields is amply proven by the increased cane yields which have followed their installation. Leaching will remove the salts, but unless some special provision is made the leaching process may not bring about the needed change in

zeolites. If a soil contains an excess of sodium or magnesium it will be, in part, toxic to plants even after leaching. Hence the operation should not stop with the leaching, if either of the above conditions exist, as the mechanical condition of the soil will be anything but optimum. In fact, some soil workers maintain that the poorly aerated condition of alkali soils is more toxic than the salts which they contain. The Arabs in the Algerian Oases have for centuries used waters containing 4,000 to 8,000 parts per million salt by the practice of frequent heavy applications and thorough drainage.

That the poorly aerated soil is toxic toward cane roots is amply demonstrated in the root excavation experiment of Alexander and Weller, in Field 11, already cited. This toxic environment is probably due to less leaching in the poor spots. In leaching salts from a field, the water does not penetrate uniformly since a field is rarely of uniform permeability. Some areas may receive water in excess of crop requirements and evaporation losses, while others may not even receive sufficient for crop requirement. There may follow then, in the poorly drained spots, a condition of partial stagnation, due to lack of air and sufficient drainage to refresh the soil solution. In this connection some recent work by Scofield (13) is of interest. In this he has shown that a further necessity for leaching the root zone is important from the standpoint of accumulation of salts rejected by the plant. Of the many inorganic constituents of irrigation water some are used very little by the plant. Crops do not absorb water and dissolved substances in the same proportion that the constituents occur in the soil solution. In his experiments, at the end of 24 days, the residual culture solutions contained 78-91 per cent of the salts originally present. Therefore, he concludes that saline irrigation water must be applied in sufficient quantities, not only to supply the crop needs and meet evaporation losses, but also to leach the root zone and carry away the salts that are left by the water which evaporates from the surface soil or is absorbed by the crop. He says that if waters contain 1,500 to 2,000 parts per million salt, 11 per cent should be allowed for root zone leaching. It will be noted in Tables VI and VII that both Fields 3D and 11 show more than a 10 per cent excess leaching through the tile drains.

In selecting a water for leaching a saline soil, mountain water would probably prove disastrous. The jelly-like property of clay in heavy soils is a direct result of the hydrolysis of sodium or magnesium ions in the zeolite complex, a property only weakly exhibited by calcium. In the presence of an excess of a sodium salt, the hydrolysis of sodium zeolite will be greatly retarded or completely stopped. The same applies to magnesium salts and magnesium zeolite. Under such conditions water should penetrate saline soils, and we know from experience that an excess of salt will flocculate most clays. On the other hand, in the absence of the respective base, or where it is present only in small amounts in the water, hydrolysis becomes active and the clay will swell to clog the interstitial spaces of the soil. Therefore, salt-free water should not be used beyond an initial reduction of salines and, following this, only after a soluble calcium salt has been added to the water. In fact, it may not be out of place to suggest an occasional application of a soluble calcium salt to our mountain water for "hard water makes soft land."

Summary

1. The nature of the soil zeolite bases in Ewa soils has been determined.
2. Except in a very few poorly drained spots zeolite sodium is not high in spite of the use of high sodium irrigation water.
3. Some Ewa soils contain more than the average zeolite magnesium and these are, on the whole, poorly drained types
4. Tile drainage has effectively reduced salt accumulation and zeolite sodium, but has not effectively reduced zeolite magnesium.
5. There is some reduction of zeolite magnesium in Field 3D, but little or none in Field 11
6 Zeolite magnesium can be reduced by gypsum, chloride of lime or ground coral rock.
7. Ewa waters are high magnesium waters and, therefore, when used on heavy clay soils, will work for better fertility if lime in some form is included in the programme of fertilization.
8. All nitrogen applications on the heavy clay types would be better applied as lime nitrate.

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Annual Synopsis of Mill Data

By W. R. McAllep and W. L. McCleery

Operating data for the year ending September 30, 1929, are presented in this Synopsis. These data represent the production of 907,081 tons of sugar, an increase of approximately 1 per cent over the previous year. While data are included from all factories in the Association, the number has been reduced from 40 to 39 as the Halawa factory is no longer operated.

At 12 factories, the operating year ending September 30 did not coincide exactly with the crop year. These factories are indicated by appropriate marks in the first of the large tables. In ten instances the 1929 crop was not finished when data were transmitted. In five instances portions of the 1928 crop, ground subsequent to September 30, 1928, are included.

Factories are listed in the tables in the order of their average production during the previous five seasons, except where otherwise noted. Operating data, together with averages for the past ten years, are in the first of the large tables. Corresponding averages for all factories except those using the Petree process, or modifications thereof, are in Table No. 3. The second of the large tables contains data on mill settings, etc. Data on cane, chemical control, milling, boiling house work, etc., are presented in a number of small tables and discussed in the text. Data on juice and surface grooving have been omitted as there has been but little change since these were previously included in 1928.

A new large table indicating capacities of factory equipment has been included this year. In a few instances figures in this table are dimensions; all others are calculated to "per ton cane hour," on the basis of rated capacity. Data in this table have been brought up to date by including improvements installed for the 1930 crop.

Varieties of Cane

Table 1 includes the same five major varieties as in 1928. In comparison with last year, increases are recorded for Yellow Caledonia and D 1135, and decreases for H 109, Yellow Tip and Striped Tip. This is the first decrease which has been recorded for H 109, and the first increase for Yellow Caledonia since 1921. However, according to Acreage Census data, the area planted to Yellow Caledonia is decreasing, and further reductions in the proportion of this variety may be expected. The increase in D 1135, while small in comparison with last season, is moderately large in comparison with 1927. Moderate increases over 1927 are also recorded for Yellow Tip and Striped Tip.

MINOR VARIETIES

One Per Cent or More of the Crop at Any Factory

Uba	.71	K 202	.16
Striped Mexican	.64	Rose Bamboo	.15
Lahaina	.57	U. D. 1	.12
Badila	.46	W 4	.05
H 456	.36	W 2	.04
K 107	.30	McBryde 6	.04
P. O. J. Canes	.26	D 117	.03
H 8965	.10	K 73	.03

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Others
H. C. & S. Co	99	..	..	.	..	1
Oahu	88	..	11	..	..	1
Ewa	97	..	..	..	..	3
Waialua	91	..	5	..	..	4
Maui. Agr	86	..	..	..	..	14
Pioneer	96	.	2	..	..	2
Olaa	..	84	16	..	..	..
Lihue	60	1	7	18	..	14
Haw. Sug	84	1	13	..	..	2
Honolulu	100	..	..	..	..	..
Onomea	..	82	5	12	..	1
Kekaha	85	..	5	..	..	10
Hilo	..	88	10	2	..	..
Haw. Agr	..	50	37	..	..	13
Wailuku	81	1	5	..	..	13
Makee	50	15	..	11	.	12
Honokaa	..	4	73	..	..	23*
Hakalau	..	76	4	20	..	
McBryde	76	3	3	2	..	16
Laupahoehoe	..	36	37	27	..	..
Kahuku	90	10	..	.	..	..
Hamakua	..	24	66	10	..	..
Pepeekeo	..	96	4	..	..	..
Paauhau	6	1	82	8	..	3
Koloa	72	2	..	20	..	6
Waiakea	..	98	1	..	..	1
Hawi	1	..	23	3	64	9
Hutchinson	..	61	31	..	..	8
Honomu	..	89	7	2	..	2
Kaiwiki	1	20	54	20	..	5
Waimanalo	82	8	8	..	..	2
Kohala	..	1	31	9	32	27†
Kilauea	6	4	4	39	4	43‡
Waianae	100	..	..	..	..	..
Kaeleku	..	100	..	..	..	..
Union Mill	..	..	24	1	75	..
Niulii	..	15	36	26	23	..
Waimea	100	..	..	..	..	..
Olowalu	97	..	..	..	..	3
True Average 1929	53.1	21.5	13.0	4.3	2.1	6.0
" " 1928	54.7	20.7	12.9	4.9	2.2	4.6
" " 1927	53.1	23.7	11.8	4.0	1.6	5.8
" " 1926	48.7	25.6	12.1	4.5	2.1	7.0
" " 1925	42.7	30.7	11.9	2.7	2.1	9.9
" " 1924	38.1	32.6	12.0	2.3	2.0	13.0
" " 1923	30.7	36.3	11.2	1.2	1.6	19.0
" " 1922	21.1	40.8	12.2	2.7	1.6	22.1
" " 1921	15.0	45.1	11.0	1.2	1.8	25.9
" " 1920	9.1	42.7	10.0	1.4	2.1	34.7

* Uba, 13%; P. O. J. canes 7%.
† Kohala seedlings.
‡ Uba, 23%; Badila, 15%.

The above tabulation probably includes all or nearly all varieties making up one per cent or more of the crop at any single factory, but it is probable that figures for the ratio of these varieties to the total crop are low in several instances as small amounts of minor varieties are not always reported separately.

The following varie ies, H 8965, McBryde 6, K 73, and the "P. O. J. canes," are included in this classification for the first time.

Quality of Cane

The quality of cane, as indicated by "quality ratio," is better than in 1927 and 1928, but poorer than in other previous years except 1923, when an identical quality ratio, 8.57, was recorded. Fiber is slightly higher than in the two previous seasons, but lower than in other seasons since 1919.

On Maui the quality ratio is better than in any season since 1920. Formerly low fiber was an outstanding characteristic of Maui cane; now the fiber is higher than on any other island. All factories on Maui report increases in fiber and all except Olowalu reported increases in 1928.

On Oahu quality ratio and also pol. are better than in any year since 1925, and the first expressed juice purity is better than in any year since 1915. Although fiber is slightly higher than last year, it is lower than on any other island.

On Kauai and Hawaii quality ratio, pol. and first expressed juice purity are all better than in the past two seasons. Fiber has decreased slightly.

The islands rank in the usual order on the basis of cane quality, that is, Maui, Oahu, Kauai, and Hawaii.

Chemical Control

Data for sucrose recovery on available and molasses produced on theoretical are in Tables 4 and 5. Gravity solids and sucrose balances are in Table 6. Data in these tables are useful for detecting avoidable losses and for checking the accuracy of the chemical control. These tables have been continued in recent Synopses largely for the purpose of studying chemical control as applied to factory operation. With improvements in factory operation in recent years the influence of discrepancies in our control methods has become more apparent. While the effect of these discrepancies is not known exactly, and, indeed, may vary somewhat under different conditions, we do know that the calculated figure for available sucrose is too low. Likewise the calculated theoretical amount of molasses is too high. These factors must be taken into consideration when interpreting factory control figures and in examining control data for errors in the application of chemical control methods.

Figures in Tables 4 and 5 indicate that the tendency toward reporting higher recoveries on available is continuing. One factory only has reported under 97 per cent against 3 so reporting last season. On the pol. basis (Table 4) 28 factories report 100 per cent or over, against a previous maximum of 26, and 11 factories report over 101 per cent against a previous maximum of 10. On the sucrose basis (Table 5) 15 factories report 100 per cent or over, against a previous maximum of 13, and two factories report over 101 per cent, the same number as last year. After

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1920					
Pol	12.86	15.29	13.75	13.07	13.64
Per cent Fiber	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice	87.87	88.91	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Pol	12.25	14.67	13.72	12.67	13.12
Per cent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Pol	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Pol	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Pol	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Pol	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Pol	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Pol	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99
1928					
Pol	11.57	14.13	13.09	12.09	12.55
Per cent Fiber	12.58	12.56	12.13	12.82	12.50
Purity 1st Expressed Juice	86.60	88.76	86.84	85.16	86.84
Quality Ratio	9.62	7.60	8.45	9.19	8.79
1929					
Pol	11.80	14.56	13.49	12.64	12.90
Per cent Fiber	12.53	13.24	12.28	12.61	12.62
Purity 1st Expressed Juice	86.65	89.14	87.17	85.97	87.18
Quality Ratio	9.58	7.39	8.20	8.76	8.57

TABLE NO. 3

True Averages of All Factories Except Those Using the Petree Process

	1924	1925	1926	1927	1928	1929
Cane—						
Pol	13.08	12.99	12.99	12.05	12.30	12.63
Fiber	12.82	12.80	12.71	12.55	12.47	12.54
Tons per ton sugar	8.40	8.45	8.50	9.24	9.03	8.75
Bagasse—						
Pol	1.52	1.54	1.58	1.50	1.53	1.55
Moisture	41.26	41.25	41.09	41.61	41.36	41.46
Fiber	56.74	56.55	56.64	56.20	56.42	56.31
Pol % cane	0.34	0.35	0.35	0.33	0.34	0.34
Pol % pol of cane	2.63	2.69	2.73	2.77	2.76	2.72
Milling loss	2.68	2.73	2.79	2.66	2.72	2.71
Weight % cane	22.59	22.63	22.44	22.33	22.11	22.26
First Expressed Juice—						
Brix	18.34	18.14	18.24	17.17	17.45	17.76
Pol	16.07	15.91	15.88	14.74	15.08	15.40
Purity	87.61	87.67	87.05	85.84	86.41	86.69
"Java ratio"	81.4	81.7	81.8	81.7	81.6	82.1
Mixed Juice—						
Brix	13.37	13.44	13.65	12.88	13.04	13.29
Pol	11.31	11.38	11.48	10.67	10.89	11.15
Purity	84.56	84.67	84.12	82.88	83.47	83.89
Weight % cane	112.66	111.03	110.10	109.71	109.87	110.18
Pol % cane	12.74	12.64	12.64	11.71	11.96	12.29
Extraction	97.37	97.31	97.27	97.23	97.24	97.28
Extraction ratio	20.5	21.0	21.5	22.1	22.1	21.7
Last Expressed Juice—						
Pol	1.84	1.90	2.06	1.88	1.94	1.99
Purity	71.73	69.63	68.72	67.76	68.39	68.73
Maceration % cane	35.30	33.06	32.54	32.04	31.99	32.44
Syrup—						
Brix	63.18	63.63	64.21	62.91	63.05	63.38
Purity	86.02	85.95	85.49	84.54	84.86	85.24
Increase in purity	1.46	1.28	1.37	1.66	1.39	1.35
Lbs. avail. CaO per ton cane	1.72	1.56	1.66	1.52	1.46	1.38
Press Cake—						
Pol	2.16	2.17	2.40	2.22	2.34	2.27
Weight % cane	2.45	2.45	2.63	2.67	2.87	2.87
Pol % cane	0.05	0.05	0.07	0.06	0.07	0.07
Pol % pol of cane	0.40	0.41	0.50	0.49	0.55	0.52
Commercial Sugar—						
Pol	97.20	97.23	97.29	97.40	97.49	97.64
Moisture	0.78	0.74	0.66	0.64	0.62	0.58
Weight % cane	11.91	11.83	11.77	10.83	11.08	11.43
Pol % cane	11.58	11.50	11.45	10.55	10.80	11.16
Pol % pol of cane	88.76	88.78	88.41	87.96	88.21	88.39
Pol % pol of juice	91.16	91.24	90.95	90.45	90.70	91.06
Deterioration factor	0.26	0.27	0.24	0.25	0.25	0.25
Final Molasses—						
Weight % cane	2.83	2.82	2.94	3.02	2.97	2.98
Sucrose % cane	0.97	0.93	0.99	1.01	0.98	0.98
Sucrose % pol of cane	7.45	7.20	7.63	8.37	8.00	7.77
Sucrose % pol of juice	7.65	7.40	7.84	8.60	8.22	7.98
Gravity solids	89.08	90.09	89.59	89.43	88.77	88.82
Gravity purity	37.81	36.97	37.62	37.40	37.41	37.13
Undetermined Losses—						
Pol % cane	0.14	0.16	0.13	0.11	0.11	0.09
Pol % pol of cane	0.76	0.92	0.73	0.41	0.48	0.40

careful study of these data and chemical control methods, together with observations in factory practice during a number of years, it is apparent that figures for "recovery on available" slightly in excess of 100 per cent, even on a sucrose basis, are not necessarily inconsistent, nor are they necessarily due to errors in the application of our fac ory control methods. There is little question but that this tendency toward higher figures for recovery on available reflects improvement in boiling house work.

Figures in Table 4 for molasses produced on theoretical are base l on the assumption that gravity solids in syrup minus gravity solids in the commercial sugar should be accounted for in the final molasses. The arithmetical average of figures for molasses per cent theoretical in Table 4 is 89.9%. The average for the past seven seasons is 90.2; averages for these seasons varying between a minimum of 88.6 and a maximum of 91.2.

Molasses figures in Table 5 are calculated from sucrose data, using the s. j. m. formula. The average on this basis is 89.1 and the average for the past 4 years 89.6. So far as we can infer from these averages, discrepancies in control methods result in a calculated theoretical figure some 10 per cent too high. While the influence of these discrepancies may vary more or less at individual factories, it seems reasonable to assume tentatively that a range of 5.0 on each side of the above average on the s. j. m. formula basis, of 89.6, should include all accurate figures; that figures above this range indicate the probability of control errors or inversion losses, and figures below this range, control errors or undetermined loss of solids. Ten factories listed in Table 5 are outside of this range: Olaa, Honolulu, Haw. Agr., Makee and Koloa being above, while Lihue, Hilo, Waiakea, Waimanalo, and Olowalu are below.

Gravity solids and sucrose balances for factories reporting on a sucrose basis are in Table 6. Small negative undetermined losses of sucrose are recorded for two factories. No negative undetermined losses of solids are reported.

Table 7 is a compilation of sucrose data. Two additional factories have reported sucrose data this year, bringing the total number so reporting to 33. These factories produce 96 per cent of the crop.

As figures for undetermined loss based on pol. are lower than the actual undetermined loss, it is of interest to determine what correction should be applied to averages for undetermined loss in the large table to arrive at an approximately correct figure. In the following comparison, figures tabulated under "sucrose basis" are averages from Table 7. Figures under "pol. basis" are averages for the same factories included in the "sucrose basis" column.

UNDETERMINED LOSS

Year	Sucrose Basis	Pol. Basis	Difference
1926	1.20	.36	.84
1927	1.13	.26	.87
1928	1.21	.28	.93
1929	1.05	.18	.87
Average..........			.88

TABLE NO. 4

APPARENT BOILING HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent pol actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co.	94.63	95.72	101.2	94.0
Oahu	91.16	93.33	102.4	91.2
Ewa	92.09	92.15	100.1	87.7
Waialua	92.18	92.14	100.0	88.0
Maui Agr.	93.52	94.82	101.4	92.3
Pioneer	92.31	92.42	100.1	87.4
Olaa	91.27	90.24	98.9	101.2
Lihue	90.15	91.08	101.0	81.2
Haw. Sug.	93.23	94.43	101.3	95.1
Honolulu	92.05	91.26	99.1	91.1
Onomea	91.44	91.96	100.6	92.4
Kokaha	91.25	91.50	100.3	86.2
Hilo	92.40	91.62	99.2	81.4
Haw. Agr.	90.47	90.19	99.7	92.2
Wailuku	91.44	91.91	100.5	93.3
Makee	87.82	87.97	100.2	93.3
Honokaa	89.56	89.88	100.4	91.7
Hakalau	92.14	93.02	101.0	89.4
McBryde	91.64	92.71	101.2	92.2
Laupahoehoe	92.84	91.45	98.5	85.3
Kahuku	91.20	93.91	103.0	91.6
Hamakua	92.89	93.86	101.0	89.0
Pepeekeo	92.81	92.85	100.0	90.2
Paauhau	89.80	90.08	100.3	85.3
Koloa	90.98	92.42	101.6	100.1
Waiakea	89.37	89.02	99.6	80.1
Hawi	89.03	89.49	100.5	95.1
Hutchinson	91.84	92.81	101.1	88.6
Honomu	92.52	93.00	100.5	94.1
Kaiwiki	90.06	90.43	100.4	93.3
Waimanalo	88.80	90.27	101.7	85.1
Kohala	90.03	90.79	100.8	85.9
Kilauea	83.96	83.49	99.4	86.9
Waianae	90.84	89.67	98.7	81.7
Kaeleku	88.66	88.23	99.5	81.6
Union Mill	88.31	89.84	101.7	...
Niulii	85.23	87.32	102.5	...
Waimea	91.51	84.99	92.9	...
Olowalu	88.13	85.72	97.3	74.5

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	94.64	95.11	100.5	90.5
Oahu	91.28	92.22	101.0	85.0
Ewa	92.22	91.08	98.8	90.2
Waialua	92.30	90.49	98.0	90.0
Maui Agr.	93.51	94.29	100.8	88.6
Pioneer	92.35	91.53	99.1	89.1
Olaa	90.76	89.93	99.1	101.6
Lihue	90.35	89.89	99.5	80.7
Haw. Sug.	93.23	93.73	100.5	91.4
Honolulu	92.35	89.67	97.1	100.7
Onomea	91.34	91.66	100.4	91.7
Kekaha	91.18	91.26	100.1	86.6
Hilo	92.15	91.36	99.1	83.7
Haw. Agr.	90.61	89.38	98.6	96.6
Wailuku	91.55	91.20	99.6	93.8
Makee	88.18	86.43	98.0	95.9
Honokaa	89.59	89.42	99.8	92.1
Hakalau	92.28	92.40	100.1	89.8
McBryde	91.70	91.81	100.1	90.5
Laupahoehoe	92.72	91.16	98.3	91.9
Kahuku	91.47	92.60	101.2	86.2
Hamakua	92.87	93.45	100.6	87.1
Pepeekeo	92.77	92.61	99.8	92.0
Paauhau	89.80	89.45	99.6	85.7
Koloa	91.17	91.45	100.3	98.1
Waiakea	89.53	88.20	98.5	83.8
Hutchinson	91.72	92.43	100.8	85.9
Honomu	92.33	92.88	100.6	92.4
Waimanalo	88.72	89.73	101.1	81.5
Kohala	90.04	90.30	100.3	84.9
Kilauea	84.02	82.55	98.3	87.5
Waianae	90.97	88.92	97.7	86.7
Olowalu	88.03	85.38	97.0	80.5

* Calculated by the S. J. M. formula.

GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice: Press Cake	Commercial Sugar	Final Molasses	Undetermined	Sucrose per 100 Sucrose in Mixed Juice: Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	3.2	84.4	11.6	0.8	0.43	94.70	4.85	0.02
Oahu	5.1	77.3	15.7	1.9	0.61	91.66	7.41	0.32
Ewa	5.6	75.1	16.7	2.6	0.46	90.66	7.02	1.86
Waialua	3.6	77.6	15.6	3.2	0.87	89.70	6.93	2.50
Maui Agr.	...	84.8	14.0	1.2	....	94.29	5.75	—0.04
Pioneer	4.5	76.6	16.3	2.6	0.36	91.20	6.82	1.62
Olaa	10.2	71.2	18.5	0.1	1.17	88.88	9.39	0.56
Lihue	4.0	74.3	17.3	4.4	0.42	89.51	7.79	2.28
Haw. Sug	4.6	79.9	14.6	0.9	0.28	93.47	6.19	0.06
Honolulu	4.8	75.6	17.5	2.1	0.36	89.35	7.70	2.59
Onomea	3.7	76.7	18.2	1.4	0.16	91.51	7.94	0.39
Kekaha	4.5	76.0	17.0	2.5	0.44	90.86	7.64	1.06
Hilo	5.2	76.3	15.0	3.5	0.35	91.04	6.57	2.04
Haw. Agr.	3.3	76.1	18.9	1.7	0.25	89.16	9.07	1.52
Wailuku	5.7	76.4	16.6	1.3	0.59	90.66	7.92	0.83
Makee	4.4	68.7	24.6	2.3	0.59	85.92	11.33	2.16
Honokaa	6.0	71.9	20.4	1.7	0.68	88.81	9.59	0.92
Hakalau	3.6	78.0	16.6	1.8	0.15	92.26	6.93	0.66
McBryde	3.2	77.0	18.1	1.7	0.53	91.32	7.51	0.64
Laupahoehoe	3.3	77.9	16.1	2.7	0.15	91.02	6.69	2.14
Kahuku	5.7	74.4	18.0	1.9	0.33	92.29	7.35	0.03
Hamakua	...	81.9	16.1	2.0	....	93.45	6.21	0.34
Pepeekeo	5.8	76.8	15.9	1.5	0.20	92.42	6.65	0.73
Paauhau	4.4	74.3	18.1	3.2	0.24	89.24	8.74	1.78
Koloa	6.0	73.4	20.5	0.1	0.58	90.92	8.66	—0.16
Waiakea	5.6	72.1	17.8	4.5	0.48	87.78	8.77	2.97
Hutchinson	6.2	75.9	15.9	2.0	0.19	92.25	7.11	0.45
Honomu	4.7	77.3	17.1	0.9	0.13	92.76	7.09	0.02
Waimanalo	6.4	70.8	19.3	3.5	0.58	89.21	9.19	1.02
Kohala	4.9	75.1	17.2	2.8	0.63	89.73	8.46	1.18
Kilauea	4.5	63.1	27.9	4.5	1.93	80.96	13.98	3.13
Waianae	3.8	74.1	17.8	4.3	0.83	88.18	7.83	3.16
Olowalu	6.5	67.5	19.3	6.7	0.56	84.90	9.63	4.91

Factory	Cane Sucrose*	Mixed Juice: Sucrose	Mixed Juice: Gravity Purity	Syrup: Gravity Purity	Syrup: Increase in Purity	Sugar: Sucrose	Sugar: Sucrose per 100 Sucrose in cane	Undetermined Loss per 100 Sucrose in cane
H. C. & S. Co.	13.24	12.38	90.37†	90.35	—0.02	97.99	92.81	0.02
Oahu	13.70	12.20	86.77	87.31	0.54	98.45	89.89	0.31
Ewa	13.45	11.37	84.28	86.30	2.02	98.36	89.13	1.82
Waialua	14.60	12.94	87.73	88.0	0.27	98.36	86.77	2.42
Maui Agr.	15.37	12.88	88.40†	88.47	0.07	97.67	92.26	—0.04
Pioneer	14.40	13.07	85.37	86.53	1.16	98.36	89.05	1.58
Olaa	12.48	11.46	85.08	86.8	1.72	97.94	85.84	0.53
Lihue	12.34	10.44	84.33	84.9	0.57	98.00	87.57	2.23
Haw. Sug.	14.66	12.54	87.14	88.13	0.99	98.14	91.61	0.06
Honolulu	13.95	12.11	87.63	88.6	0.97	100.0	86.63	2.51
Onomea	11.35	9.96	84.41	85.6	1.19	97.81	89.78	0.35
Kekaha	13.77	12.44	84.80	86.12	1.32	98.14	88.93	1.04
Hilo	11.83	10.46	85.32	86.48	1.16	97.43	89.30	2.00
Haw. Agr.	12.07	12.07	86.28	86.82	0.54	98.21	86.72	1.48
Wailuku	13.50	10.99	85.92	87.6	1.68	98.00	88.99	0.81
Makee	11.29	10.13	81.37	81.8	0.43	97.56	82.33	2.07
Honokaa	10.74	9.82	82.59	84.22	1.63	97.86	84.42	0.88
Hakalau	11.74	9.86	84.56	85.66	1.10	96.95	90.95	0.65
McBryde	13.59	11.77	84.98	85.22	0.24	97.78	88.03	0.61
Laupahoehoe	12.33	10.47	86.60	87.24	0.64	98.25	88.37	2.07
Kahuku	11.82	10.45	82.41	84.05	1.64	98.12	90.21	0.03
Hamakua	12.13	12.05	86.63†	86.74	0.11	98.39	89.97	0.33
Pepeekeo	12.21	11.00	84.36	86.76	2.40	98.05	90.33	0.71
Paauhau	11.25	9.41	83.87	85.27	1.40	97.42	87.07	1.74
Koloa	11.74	10.15	82.18	84.3	2.12	98.21	88.21	—0.15
Waiakea	12.00	10.16	82.87	84.91	2.04	97.23	84.34	2.85
Hutchinson	13.33	12.23	84.63	85.80	1.17	97.46	89.63	0.44
Honomu	11.92	9.85	83.90	86.27	2.37	98.39	91.10	0.02
Waimanalo	12.56	10.40	80.69	82.43	1.74	97.09	87.95	1.00
Kohala	11.92	9.69	84.26	85.99	1.73	97.62	87.21	1.15
Kilauea	9.60	9.16	78.15	78.6	0.45	97.42	77.52	2.99
Waianae	14.18	12.61	84.46	85.18	0.72	97.61	85.57	3.06
Olowalu	13.16	10.68	81.02	82.75	1.73	96.93	83.08	4.81
‡True Average 1929	13.08	11.44	85.58	86.60	1.02	98.00	88.75	1.05
" " 1928	12.69	11.22	85.15	86.23	1.08	97.86	88.49	1.21
" " 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Pol in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane
† Clarified juice. ‡ Refinery data from Honolulu not included in averages.

According to the above, adding .88 to crop averages for undetermined loss in the large table should give approximately correct figures. With this correction the 1929 figures for undetermined loss become 1.12 per cent.

There has been no increase in the number of factories weighing mixed juice and molasses. Mixed juice is weighed at 35 factories and measured at 4. Molasses is weighed at 28 factories, and measured at 8. Neither weights nor measurements are reported from 3 factories.

pH data are reported from 34 factories. While this is one less than last year, the reduction is due to closing Halawa factory. Three additional factories report clarified juice turbidity, bringing the total so reporting to 27.

Attention is again called to averages in Table 3 for factories that do not use the Petree process and to the necessity of consulting these data when drawing inferences from yearly averages, because of the disturbing effect of data from Petree process factories on many of the averages in the large table.

Milling

Milling work is appreciably better than in the previous season, although both the average grinding rate and fiber in cane are higher than last year. On the other hand, extraction has been somewhat favored by higher pol. in cane. The average extraction has increased from 97.26 to 97.35, the extraction ratio has decreased from 21.9 to 21.0, and the milling loss has decreased from 2.75 to 2.72. The improvement has brought the extraction to a higher point than in previous seasons except 1920 and 1921, and has reduced the milling loss to a lower point than in any previous season except 1921. Higher extraction is reported from 22 factories, while lower extraction ratio and lower milling loss are each reported from 17 factories. The improvement in milling work, however, may be attributed mainly to results at the larger factories, as 8 of the 10 larger factories report better work.

A condensed tabulation of milling data follows:

Year	Tons cane per hour	Tonnage ratio	Tonnage fiber ratio	Tons pressure per linear ft. roller	Maceration per cent cane	Milling loss	Extraction ratio	Extraction
1921	36 58	1.40	17.9	. . .	39.30	2.64	20.1	97.43
1922	39 93	1.54	19.9	65 2	34.75	3.02	23.3	96.98
1923	42.03	1.56	20.0	66.2	35.12	2.76	21.6	97.23
1924	43.63	1.62	20.6	66.9	34.90	2.78	21.0	97 33
1925	45.31	1.71	21.8	66.5	33.63	2.82	21.3	97.29
1926	46 43	1 78	22.5	67.4	33.61	2.88	21.7	97.25
1927	47.87	1.78	22 2	68.2	32.53	2.73	22.2	97.23
1928	49.30	1.83	22.9	70.5	32 16	2.75	21.9	97.26
1929	50.98	1.89	23.9	70.4	33.26	2 72	21.0	97.35

This is the eighth consecutive season for which increases in the average grinding rate are recorded. During this period the average figure for tons of cane

ground per hour has increased 40 per cent. Twenty-seven factories report increases this season.

Eighteen factories report increases in pressure against eight reporting decreases. The average for tons pressure per foot of roller has not increased, as moderately large decreases at three or four factories have offset increases reported from a considerable number.

Maceration per cent cane is 1 10 higher than last year, bringing the average to 33.26. This is the first time in seven years that an increase in maceration has been reported. The tendency toward an increase has not been general, the number of factories reporting increases and decreases being practically the same.

The average pol. in bagasse has decreased from 1.55 to 1.54. The improvement is not general, as lower figures are reported but from 16 factories. Moisture in bagasse has decreased from 41.48 to 41.24, the latter figure being lower than in any season except 1920 and 1921. In this case also, but 16 factories report lower figures, so the improvement cannot be considered general.

The purity drop from first expressed to mixed juice in non-Petree process factories has decreased from 2.94 to 2 80. The best previous figure was 2.90, attained in 1923. The purity drop between first expressed and last expressed juice also has decreased, the average being 18.10 this year, against 18.35 in 1928. Reducing these purity drops and at the same time obtaining higher extraction reflects an appreciable improvement, which may be attributed to better mill sanitation, to reduction in the amount of field trash, or to both of these factors. An increase in Java ratio, notwithstanding an increase in cane fiber, tends to corroborate this observation The Java ratio has increased from 81.5 to 82.0; the highest figure in ten years.

But few additions have been made to milling equipment. A Krajewski crusher has been installed at Olaa and knives have been installed at Kekaha, Onomea, and Waianae, the latter installation being a second set. Increased maceration at a number of the larger factories in combination with the same or heavier pressure appear to be major factors in the improvement in milling work.

Factories are listed in the order of the size of their milling loss in Table 8. Waimanalo, Hakalau and Onomea are again in first, second, and third positions respectively. The first five factories in this table have been at the head of the list for the last three years. Factories that have bettered their position five places or more are: Olowalu, Hawaiian Sugar, H. C. & S. Co., Pioneer, Waimea and Makee. Two of these factories report decreases and four increases in grinding rate. All except Waimea report increases in maceration. The following have dropped five places or more: Hawi, Kilauea, Hamakua, and Waialua. All of these factories report decreases in maceration and increases in grinding rate.

The previous record of 9 factories reporting 98 extraction or over has been equalled this season. Six factories report under 2.0 milling loss, against 5 last year and a previous maximum of 8. No factory has equalled either the previous record of 99.07 for extraction, made at H. C. & S. Co. in 1921, or the previous record of 1.08 for milling loss made at Hakalau in 1925.

TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

Rank	1928 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Maceration	Tonnage Ratio	Tonnage Fiber Ratio*
1	1	Waimanalo....	1.34	10.7	98.58	40.21	2.08	27.52
2	2	Hakalau.......	1.34	11.5	98.57	38.23	1.71	21.10
3	3	Onomea......	1.74	15.4	98.10	33.45	2.05	25.28
4	5	Honomu.......	1.76	14.9	98.20	38.97	1.47	17.82
5	4	Hilo..........	1.78	15.1	98.08	33.17	1.95	24.78
6	10	Ewa..........	1.82	13.4	98.20	39.13	1.68	21.47
7	8	Paauhau.. . .	2.04	18.3	97.54	39.57	1.14	15.29
8	7	Wailuku	2.06	15.4	98.14	40.77	1.29	15.54
9	14	Olowalu.... ..	2.09	16.0	97.82	42.83	1.54	20.96
10	11	Lihue.... ..	2.20	18.1	97.79	37.05	2.29	27.94
11	13	Oahu..........	2.22	16.4	98.04	30.99	1.94	23.18
12	9	Kahuku.......	2.23	19.3	97.72	30.71	1.63	19.30
13	12	Pepeekeo	2.24	18.5	97.72	29.54	1.97	24.27
14	21	Haw. Sug.....	2.27	15.6	98.00	36.59	1.71	21.89
15	26	H. C. & S. Co.	2.27	14.8	97.99	43.01	1.78	23.82
16	15	Kekaha......	2.47	18.1	97.86	28.59	1.97	23.25
17	25	Pioneer.......	2.49	17.5	97.62	32.61	2.29	31.17
18	22	Maui Agr.....	2.54	16.6	97.83	39.74	1.91	24.91
19	6	Hawi.........	2.55	21.1	97.16	24.56	1.81	24.36
20	19	Kohala........	2.67	22.6	97.15	41.53	1.59	20.07
21	17	Koloa.........	2.74	23.6	96.98	33.90	1.33	17.01
22	18	Haw. Agr.....	2.76	23.2	97.23	18.25	2.01	24.04
23	30	Waimea	2.81	20.7	97.38	27.33	1.56	19.75
24	23	Laupahoehoe ..	2.86	23.3	97.07	35.78	1.68	21.15
25	24	Hutchinson...	2.92	22.0	97.15	27.48	1.92	24.83
26	20	Kilauea... ...	3.32	35.0	95.70	22.78	1.74	21.37
27	36	Makee....... .	3.48	31.4	95.74	31.20	2.25	30.53
28	31	Waianae.......	3.49	25.0	97.00	30.31	1.38	18.93
29	16	Hamakua......	3.61	30.2	96.24	19.54	1.42	17.69
30	29	Olaa..........	3.63	29.1	96.56	27.39	2.05	24.27
31	32	Waiakea.. .	3.66	30.9	96.03	37.38	1.66	21.35
32	28	McBryde......	3.67	27.2	96.36	35.55	1.52	20.32
33	27	Waialua.......	3.73	26.1	96.66	33.23	2.59	33.10
34	34	Honolulu......	3.76	27.4	96.91	31.97	1.89	21.34
35	35	Kaiwiki.......	4.13	33.3	95.74	26.40	1.76	22.55
36	37	Kaeleku.......	4.21	35.2	94.98	32.28	1.88	26.08
37	33	Honokaa......	4.26	40.0	95.02	28.21	1.68	20.90
38	38	Niulii...	4.94	48.6	93.15	26.24	1.85	26.18
39	40	Union Mill....	6.16	54.6	92.12	20.57	1.69	24.39

*Tonnage ratio multiplied by per cent fiber in cane.

Data from H. C. & S. Co. furnish additional information on the effect of returning mud to the mill; a subject which has been of considerable interest in Hawaii since the introduction of the Petree process. At this factory Peck strainers covered with 100- to 150-mesh screens are used for the mixed juice. The settlings are concentrated in Kopke centrifugal separators, reducing the moisture content to about 76 per cent, and the pol. to between 2 5 and 3.0 per cent. In 1928 the mud from the Kopke separators was returned to the mill. In 1929 the mud was discarded. The reported extraction improved from 97.35 to 97.99, notwithstanding an increase of .68 in cane fiber. These extraction figures, however, are not exactly comparable, as the increase in the amount of bagasse, corresponding to the returned mud, was not taken into consideration in calculating the 1928 extraction. Assuming the same proportion of mud as in 1929, this correction is equivalent to .10 in extraction and the corrected gain in extraction becomes .74. Subtracting the 1929 loss in Kopke mud, 43 leaves a net reduction in losses of .31. Although the grinding rate was 1.34 tons less than in 1928, on account of higher fiber in the cane, the operating capacity as indicated by tonnage-fiber ratio figures, was 3 per cent greater. Moisture in bagasse was decreased from 41.97 to 38.24, and maceration was increased from 35.75 to 43.01, indicating the probability that the improvement in extraction is due both to more effective application of pressure and to ability to apply heavier maceration.

Boiling House Work

Data for boiling house work indicate an improvement in this department also, although one important detail, clarification, is less satisfactory than last year.

Clarification: Referring to data for non-Petree process factories in Table 3, we find that with a decrease of .08 pound in the amount of CaO per ton of cane, the increase in purity from mixed juice to syrup is .04 less than last year. Higher grinding rates in the last few years, with but little increase in facilities for filtering settlings, have rendered it much more difficult to approximate the range of 8.0 to 8.3 pH in the hot limed juice indicated by experimental work as the optimum clarification reaction. Two-thirds of the factories reporting the pH of the hot limed juice, report under 8 pH. There is little question but that the average clarification reaction is below the optimum range and that benefits would accrue if the amount of lime could be increased. Low clarification pH is due principally to the practical necessity of keeping the volume of settlings within the capacity of available filtration equipment. Handling the settlings satisfactorily is the outstanding problem of our present boiling house practice.

Notwithstanding the smaller increase in purity during clarification, the difference between first expressed juice and syrup purity has decreased from 1.58 to 1.46, due to the smaller drop between first expressed and mixed juice purities mentioned in a preceding paragraph. The difference this year is smaller than in recent years except 1923 and 1927, when considerably better increases in purity during clarification were secured.

Filter Presses: The loss in press cake per cent pol. in cane (Table 3) has been reduced from .55 to .52. The improvement is due to a reduction of .07 in pol., the weight of press cake remaining the same. The figure in the large table for loss in press cake for all factories is the same as last year. This is because the loss in Kopke mud at H. C. & S. Co., which did not appear as a loss in press cake last year, has offset reductions in filter press loss at other factories.

Evaporation: Evaporator capacity has been increased at four factories: Maui Agr., Lihue, Kekaha, and Waiakea. All of these factories report increases in syrup density. The average is 63.65 Brix; an increase of .61 over last year. The calculated amount of water evaporated per hour has increased 4.2 per cent.

Commercial Sugar: The pol. of the commercial sugar has increased .13, bringing the average to 97.64, a higher figure than in any previous season. This is the tenth successive season in which increases in sugar pol. have been recorded. The increase in the average is due to increases at factories shipping sugar to Crockett. Higher pol. has been quite general in this group, 19 of the 28 factories reporting increases. The average pol. at factories shipping to the Western refinery has decreased .03, although seven of these factories report increases against 3 reporting decreases. The average pol. for factories shipping to Crockett is 97.75, against an average of 96.88 for factories shipping to the Western refinery.

Data for deterioration factor and low grade sugar purity, are presented in Table 9. Pol. and moisture in commercial sugar are also included, together with marks indicating to which refinery the sugar is shipped. Moisture in commercial sugar has been reduced from .62 to .58. The reduction in moisture has been in slightly greater proportion than the increase in pol., with the result that the deterioration factor has been reduced from .249 to .246. These averages for both moisture and deterioration factor are the lowest on record.

While the average deterioration factor has been decreasing in recent years there is still room for improvement. A deterioration factor of .25 is considered the dividing line between a safe and unsafe moisture content, for experimental work has demonstrated that deterioration is possible above .25. The average deterioration factor, however, is above .25 at 13 of the 36 factories reporting this figure, and just .25 at 7 more of these factories.

Final Molasses: The average for final molasses purity has been reduced to 37.02. This is an improvement of .30 over the previous record, made in 1925. Twenty-three factories have reported decreases in molasses purity, against 15 reporting increases. The lowest average for an individual factory, 32.53, is reported from Kahuku. This, however, does not equal the record, 31.81, established by this factory in 1927. The loss of sucrose in molasses per cent pol. in cane has been reduced from 7.71 to 7.40.

TABLE NO. 9

SUGAR DATA

Factory	Commercial Sugar			Low Grade Sugar Purity
	Pol	Moisture	Deterioration Factor	
H. C. & S. Co.	97.77	0.53	0.24	73.3
Oahu	98.23	0.42	0.24	79.13
Ewa	97.92	0.50	0.24	79.68
Waialua	97.99	0.53	0.26	74.85
Maui Agr.	97.52	0.62	0.25	71.74
Pioneer	98.08	0.42	0.22	76.49
Olaa	97.55	0.60	0.24	77.0
Lihue	97.62	0.60	0.25	75.2
Haw. Sug.	97.95	0.54	0.26	84.38
Honolulu†	....	...	...	80.1
Onomea	97.42	0.68	0.26	79.98
Kekaha	97.65	0.59	0.25	74.71
Hilo	96.99	0.78	0.26	78.17
Haw. Agr.	98.02	0.45	0.23	79.59
Wailuku	97.46	0.60	0.24	73.0
Makee	97.19	0.74	0.26	73.35
Honokaa	97.49	0.62	0.25	66.0
Hakalau*	96.57	0.83	0.24	73.1
McBryde	97.61	0.62	0.26	78.7
Laupahoehoe	97.94	0.53	0.26	77.04
Kahuku	97.91	0.50	0.24	80.35
Hamakua	97.75	0.50	0.22	74.34
Pepeekeo	97.59	0.49	0.20	75.61
Paauhau*	96.76	0.77	0.24	80.30
Koloa	98.00	0.49	0.25	75.3
Waiakea	96.93	0.85	0.28	77.0
Hawi	97.49	0.61	0.24	75.19
Hutchinson*	97.13	0.60	0.21	72.37
Hononmu	98.02	0.45	0.23	79.08
Kaiwiki	96.89	0.78	0.25	86.48
Waimanalo*	96.51	0.70	0.20	71.74
Kohala	97.24	0.71	0.26	77.90
Kilauea*	97.23	0.81	0.29	72.8
Waianae*	97.08	0.76	0.26	79.82
Kaeleku*	97.31	...	...	78.50
Union Mill	96.85	0.99	0.31	81.50
Niulii*	96.64	1.5	0.45	78.2
Waimea	96.81	...	...	80.3
Olowalu*	96.37	0.90	0.25	78.03
True Average	97.64	0.58	0.246	76.56

* Sugar shipped to Western Refinery. Other factories except Honolulu ship to Crockett.
† Refined sugar.

Factories are grouped according to molasses purity in the following table:

GRAVITY PURITY FINAL MOLASSES

32—33	33—34	34—35	35—36	36—37
Kahuku	Hamakua	Honomu	Laupahoehoe	Hilo
	Koloa	Pepeekeo	Haw. Sug.	Waianae
		Ewa	Onomea	Makee
		McBryde	Hutchinson	Maui Agr.
		Hakalau		H. C. & S.
		Pioneer		Lihue
				Waimanalo

37—38	38—39	39—40	Over 40
Kekaha	Kilauea	Oahu	Olaa
Honolulu	Hawi	Paauhau	Kaeleku
Honokaa	Olowalu	Waiakea	Haw. Agr.
Waialua		Wailuku	Kohala
			Niulii
			Kaiwiki
			Union Mill

This classification brings out the advantage of crystallization in motion over the older low grade practice. None of the factories where low grade massecuite is boiled blank and crystallized in storage tanks report under 38 purity. Four of the seven factories reporting over 40 purity follow this practice.

Crystallizers have been installed at one factory, Waiakea, and an improvement of 3.20 in final molasses purity has been realized. In the last three years crystallizers have been installed at four other factories, Laupahoehoe, Hamakua, Hutchinson and Waianae, and in each instance material benefits have accrued. At each of these factories, molasses purities averaged 40 or above in seasons immediately preceding the installation of crystallizers. Improvements in molasses purity since these installations are the equivalent of from 1 to 3 per cent in recovery. The superiority, from a practical standpoint, of boiling to grain and crystallization in motion, over blank boiling and crystallization in storage tanks has been demonstrated conclusively by operating data in recent years. There is little question as to the advisability of making the change at factories still following the older practice.

Undetermined Loss: The undetermined loss has decreased from .32 to .24, the latter figure being the lowest on record. These figures on a pol. basis, however, are lower than the actual undetermined loss. As pointed out under "Chemical Control," the probable correction is .88, making the 1929 average 1.12 instead of .24 per cent.

Recovery

The recovery has again increased, the improvement being due in part to higher purity juices and in part to better factory work.

The boiling house recovery has increased from 91.24 to 91.65. This is the highest figure since 1909, at which time higher purities rendered it possible to attain high boiling house recoveries with far less efficient factory work.

The total recovery has increased .47, bringing it to 89.23, the highest figure on record. Higher pol. in commercial sugar corresponds to a decrease of .05 in re-

covery, so, in making a comparison with last year, we may consider that the improvement is .52 rather than .47.

Assuming that the improvement in first expressed juice purity reflects the improvement in the purity of the cane juice as a whole, approximately one-half of the increase in recovery may be attributed to higher purity raw material. The remaining half may be divided approximately as follows: a third to better low grade work, a third to better extraction and lower undetermined losses, and a third to a smaller drop in purity from first expressed to mixed juice.

Comparison of quality ratio data with tons cane per ton of sugar also divide the improvement between better cane and better factory work. It will be noted, however, that this comparison is not on the same basis as the above, figures referring to yield per cent cane instead of yield per cent pol. in cane. Quality ratio figures indicate that an increase of .29 in yield of sugar per cent cane should be secured while .38 was realized. If we correct the former figure for the increase in fiber and the latter for the increase in sugar pol., these figures become .27 indicated increase and .39 obtained.

Comparison of Actual and Calculated Recoveries

Comparisons in Table 10 are identical with those in the two previous Synopses. Recoveries are compared first with the recovery of a hypothetical factory having no losses other than in final molasses reduced to 37.5 gravity purity, and second, with recovery indicated by "sugar ratio." Factories are listed in the table in the order indicated by the first of these comparisons. The order shown by the second is indicated by figures in next to the last column. No attempt has been made to indicate inaccuracies in control data, which seriously influence the comparative standing determined in this way, though this has been done in previous years. While careful examination will usually give a fair idea of the probable accuracy of control data, it is hardly practicable to decide which data should be designated as inaccurate except on the basis of definite standards. Such standards must be arbitrarily chosen and it is extremely difficult to formulate a set of standards which will be equitable in all cases. It has seemed preferable at this time to present the results of these comparisons at their face value, without attempting to indicate instances where figures for relative standing have been influenced by unreasonably large errors in chemical control. In connection with examining control data for such errors we would note that percentage figures in columns 2 and 3 refer to standards which can be exceeded in practice, and therefore figures of over 100 per cent are not necessarily inconsistent. It is also possible to exceed the "sugar ratio" standards.

Examination of data in Table 10 will disclose considerable differences in the relative standing indicated by these two methods. Some of the larger differences are because purities used in the "sugar ratio" calculations do not coincide closely with actual syrup purities. To a considerable extent, however, these differences in relative standing are due to a deficiency inherent in calculations of this kind. Relative results vary according to the standard chosen for final molasses purity. In one case 37.5, and in the other 33.3 has been used. These comparisons have been

TABLE NO. 10

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

		Recovery % Calculated Recovery			Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
1	Kahuku	97.72	105.13	103.04	1	102.78
2	Hakalau	98.57	102.00	100.78	2	100.57
3	Waimanalo	98.58	101.39	100.23	11	99.38
4	Honomu	98.20	101.71	100.19	7	100.02
5	Koloa	96.98	102.87	100.18	10	99.41
6	Maui Agr.	97.83	101.77	99.92	3	100.30
7	Haw. Sug.	98.00	101.61	99.78	4	100.28
8	Onomea	98.10	101.05	99.46	5	100.07
9	Ewa	98.29	100.84	99.40	12	99.36
10	Oahu	98.04	101.05	99.36	8	99.85
11	Hamakua	96.24	102.62	99.20	18	98.19
12	H. C. & S. Co	97.99	100.91	99.14	6	100.06
13	Lihue	97.79	100.89	99.05	15	98.68
14	Pepeekeo	97.72	101.16	98.92	9	99.53
15	Hutchinson	97.15	101.47	98.89	14	98.85
16	Pioneer	97.62	100.87	98.78	13	99.04
17	McBryde	96.36	101.92	98.56	19	97.90
18	Kekaha	97.86	99.99	98.29	17	98.37
19	Hilo	98.08	99.37	97.71	16	98.38
20	Wailuku	98.14	99.10	97.52	22	97.11
21	Hawi	97.16	99.45	97.05	26	96.32
22	Paauhau	97.54	99.14	96.89	25	96.51
23	Makee	95.74	100.34	96.69	31	94.55
24	Laupahoehoe	97.07	99.21	96.57	23	96.76
25	Kohala	97.15	98.97	96.42	20	97.40
26	Honolulu	96.91	98.87	96.11	21	97.18
27	Waialua	96.66	98.91	96.02	24	96.62
28	Haw. Agr.	97.23	98.30	95.79	27	96.14
29	Waianae	97.00	98.42	95.76	28	95.44
30	Honokaa	95.02	99.68	95.18	30	94.65
31	Waiakea	96.03	98.15	94.67	33	93.96
32	Kaiwiki	95.74	98.14	94.34	29	94.69
33	Olowalu	97.82	96.01	94.31	34	92.94
34	Olaa	96.56	96.77	93.79	32	94.37
35	Kilauea	95.70	96.84	93.45	36	91.42
36	Kaeleku	94.98	96.90	92.45	35	91.89
37	Niulii	93.15	98.51	92.41	38	90.63
38	Union Mill	92.12	97.79	90.56	37	90.92
39	Waimea	97.39	92.28	90.12	39	90.30

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses.

† The basis of this calculation is 98.03 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses.

continued in the Synopsis pending the development of a better method for comparing factory work, for, notwithstanding the deficiency noted above, which renders such calculations unsuitable for close comparisons, these calculations do give a fair general idea of relative results secured at different factories except in cases where there is evidence of unreasonably large discrepancies in control data.

The summary of losses is given in the usual form in Table 11.

Calculations in this Synopsis have been made by A. Brodie with the assistance of others in this department.

FACTORY	POUNDS POL PER TON OF CANE						POL PER 100 CANE						POL PER 100 POL OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	6.0	1.4	14.4	...	—1.8	20.0	0.30	0.07	0.72	...	—0.09	1.00	2 01	0.43	4.70	..	—0.61	6.62	89 60	H. C. & S. Co.
Oahu	5.4	1.6	19.8	1.2	—3.6	24.4	0.27	0.08	0.99	0.06	—0.18	1.22	1.96	0.60	7.37	0 44	—1.31	9.06	86.42	Oahu
Ewa	4.6	1.2	18.6	...	1.8	26.2	0.28	0.06	0.93	...	0.09	1.31	1.71	0.47	7.01	...	0.67	9 86	85.21	Ewa
Waialua	9 6	2.4	19.6	...	2.0	33.6	0.48	0.12	0.98	...	0.10	1.68	3.34	0.86	6.84	...	0.69	11.73	87.0	Waialua
Maui Agr.	6.6	...	17.4	...	—1.8	22.2	0.33	...	0.87	...	—0.09	1 11	2.17	...	5.67	...	—0.60	7.24	87.80	Maui Agr.
Pioneer	6.8	1.0	19.2	...	1.8	28.8	0.34	0.05	0.96	...	0.09	1.44	3.38	0.36	6.71	...	0.64	10.12	85.68	Pioneer
Olaa	8.6	2 8	23.0	...	0.4	34.4	0.48	0.14	1.13	...	0.02	1.72	3.44	1.14	9.14	...	0.18	13.90	86.5	Olaa
Lihue	5.4	1.0	18.8	...	2.2	27.4	0.27	0.05	0.94	...	0.11	1.37	2 21	0.42	7.74	...	0.91	11 31	83 8	Lihue
Haw. Sug.	5.8	0.8	17.8	...	—2.0	22.4	0.29	0.04	0.89	...	—0.10	1.12	2.00	0.28	6.12	...	—0.08	7.72	87.12	Haw. Sug.
Honolulu	8.4	1.0	20.8	0.2	...	...	0.42	0.05	1.04	0.01	....	....	3.09	0.35	7.60	0.10	....	.....	87.4	Honolulu
Onomea	4.2	0.4	17.6	...	0.0	23.2	0.21	0.02	0.88	...	0.00	1.11	1.90	0.16	7 84	...	0.04	9.94	84.87	Onomea
Kekaha	5.8	1.2	20.6	...	2.0	29.6	0.29	0.06	1.03	...	0.10	1.48	3.14	0.13	7.53	...	0.75	10.85	83.28	Kekaha
Hilo	4.6	0.8	15.2	...	4.0	24.6	0.23	0.04	0.76	...	0.20	1.23	1.92	0.31	6.49	...	1.70	10 45	85.89	Hilo
Haw. Agr.	6.6	0.6	21.4	...	1.4	30.0	0.33	0.03	1.07	...	0.07	1 50	3.77	0.26	8.91	...	0.61	12.54	85.04	Haw. Agr.
Wailuku	5.0	1.6	21.0	...	0.0	27.6	0.25	0 08	1.05	...	0.00	1.38	1.86	0.58	7.88	...	0.01	10.33	86 5	Wailuku
Makee	9.4	1.2	24.6	...	0.8	36.0	0.47	0 06	1.23	...	0.04	1.80	4.36	0.57	11.09	...	0.36	16.28	80.5	Makee
Honokaa	10.6	1.4	19.6	...	0.8	32.1	0.58	0.07	0.98	...	0.04	1.62	4.98	0.65	9 20	...	0.35	15.18	83.31	Honokaa
Hakalau	3.4	0.4	16.0	...	—0.2	19.6	0.17	0.02	0.80	...	—0.01	0.98	1.43	0.15	6 91	...	—0.04	8.45	84.62	Hakalau
McBryde	9 8	1.4	19.6	...	—0.8	30.0	0.49	0.07	0.98	...	—0.04	1 50	3.64	0.52	7.32	...	—0.34	11.14	84.42	McBryde
Laupahoehoe	7.2	0.4	16.0	...	4.2	27.8	0.36	0.02	0.80	...	0.21	1.39	2.98	0.15	6 54	...	1.71	11.30	86.60	Laupahoehoe
Kahuku	5.2	0.8	17.0	...	—3.2	19.8	0.26	0.04	0.85	...	—0.16	0.99	2.38	0.32	7.31	...	—1.37	8 54	82.01	Kahuku
Hamakua	9.0	...	14.6	...	—0.4	23.2	0.45	...	0.73	...	—0.02	1.16	3.70	...	6.05	...	—0.14	9.67	85.72	Hamakua
Pepeekeo	5.6	0.4	13.8	...	1.0	22.8	0.28	0.02	0 70	...	0.05	1.14	2.28	0.10	6 55	...	0.12	9.44	85.89	Pepeekeo
Paauhau	5.4	0.6	19.2	...	2 2	27 4	0.27	0.03	0.96	...	0.11	1.37	2.46	0.24	8.65	...	1.00	12.35	84.21	Paauhau
Koloa	7 0	1.2	19.8	...	—2.8	25.2	0.35	0.06	0.99	...	—0.14	1.26	3.02	0.57	8.50	...	—1 20	10.89	83.3	Koloa
Waiakea	9.4	1.2	20.2	...	4.6	35.4	0 47	0.06	1.01	. .	0.23	1.77	3.97	0.46	8.52	...	1.97	14.92	83 98	Waiakea
Hawi	6.8	1.2	24.8	...	—0.2	32.0	0.34	0.06	1.24	...	—0.01	1.63	2.84	0.47	10 21	...	—0.05	13.17	83.31	Hawi
Hutchinson	7 6	0.4	18.4	...	0.0	26.4	0.38	0.02	0.92	...	0.00	1.32	2 85	0.19	6.06	...	0.01	10.01	85.13	Hutchinson
Honomu	4.2	0.4	16.6	...	—0.4	20.8	0 21	0.02	0.83	...	—0 02	1.04	1.80	0.13	7.00	...	—0 14	8.79	85.69	Honomu
Kaiwiki	10.6	1.8	22.2	...	0.4	35.0	0.53	0.09	1.11	...	0 02	1.75	4.26	0.71	8.96	...	0.13	14.06	85.30	Kaiwiki
Waimanalo	3 6	1.4	22.8	...	1.0	28.8	0.18	0.07	1.14	...	0.05	1.44	1.12	0.58	9 16	...	0.38	11 54	81.55	Waimanalo
Kohala	6.8	1.4	19.6	...	1.4	29.2	0.34	0.07	0.98	...	0.07	1.16	2.86	0 62	8.29	...	0.60	12.36	85.12	Kohala
Kilauea	8 2	3.6	25.6	...	3.6	11.0	0.41	0.18	1.28	...	0.18	2.05	4.30	1.87	13.55	...	1 04	21.66	77.8	Kilauea
Waianae	8 4	2.4	21.6	...	6.2	38.6	0.42	0.12	1.08	...	0.31	1.93	3.00	0.83	7.70	...	2.23	13.76	84 06	Waianae
Kaeleku	12.0	3.3	21.8	...	4.6	41.6	0 60	0.16	1.09	...	0.23	2.08	5.02	1 29	9 08	...	1.94	17 33	83.54	Kaeleku
Union Mill	17.8	3 8	...	...	20.4	41.0	0.89	0.14	...	...	1.02	2.05	7.88	1.21	....	...	9.05	18.14	84.7	Union Mill
Niulii	14.0	2.8	...	...	23.8	40.6	0.70	0.14	...	...	1.19	2.03	6.85	1.41	....	...	11.64	19.90	80 77	Niulii
Waimea	7.2	1 2	...	...	39.4	47.8	0 36	0.06	...	...	1 97	2.39	2 62	0 43	..	...	14.55	17.80	85.54	Waimea
Olowalu	5.6	1 4	21.8	...	11.4	43.2	0.28	0.07	1.24	...	0.57	2.16	2.18	0.55	9 52	...	4.37	16.62	81.80	Olowalu

Sugar Prices

96° Centrifugals for the Period December 16, 1929 to March 15, 1930

Date	Per Pound	Per Ton	Remarks
Dec. 16, 1929	3.865¢	$77.30	Porto Ricos, 3.86; Cubas, 3.87.
" 17	3.80	76.00	Cubas.
" 19	3.77	75.40	Cubas.
" 26	3.74	74.80	Cubas.
" 27	3.77	75.40	Cubas.
" 30	3.777	75.55	Porto Ricos, 3.875; Philippines, 3.77.
" 31	3.80	76.00	Porto Ricos.
Jan. 2, 1930	3.822	76.45	Philippines, 3.815; Cubas, 3.83.
" 3	3.83	76.60	Cubas.
" 4	3.80	76.00	Cubas.
" 6	3.815	76.30	Philippines, 3.80; Cubas, 3.80, 3.83; Porto Ricos, 3.80.
" 7	3.83	76.60	Cubas.
" 8	3.80	76.00	Porto Ricos.
" 10	3.796	75.93	Cubas, 3.77, 3.83; Porto Ricos, 3.80, 3.785.
" 13	3.77	75.40	Cubas.
" 16	3.815	76.30	Porto Ricos, 3.80; Cubas, 3.83.
" 17	3.69	73.80	Cubas, 3.71, 3.67.
" 18	3.655	73.10	Philippines. 3.64; Porto Ricos, 3.67.
" 20	3.64	72.80	Cubas.
" 21	3.61	72.20	Cubas, Philippines.
" 22	3.595	71.90	Porto Ricos, 3.58; Philippines, 3.61.
" 24	3.58	71.60	Philippines.
" 28	3.61	72.20	Philippines.
" 29	3.77	75.40	Cubas.
" 30	3.716	74.33	Porto Ricos, 3.67, 3.71; Cubas, 3.77.
Feb. 1	3.71	74.20	Philippines.
" 3	3.64	72.80	Porto Ricos.
" 4	3.675	73.50	Porto Ricos, 3.58; Cubas, 3.77.
" 5	3.656	73.13	Porto Ricos, 3.58; Philippines, 3.62; Cubas, 3.77.
" 6	3.64	72.80	Porto Ricos.
" 11	3.61	72.20	Porto Ricos.
" 14	3.55	71.00	Philippines.
" 18	3.515	70.30	Porto Ricos, 3.50; Philippines, 3.53.
" 19	3.565	71.30	Porto Ricos, 3.55, 3.565, 3.58.
" 20	3.55	71.00	Philippines, Porto Ricos.
" 25	3.565	71.30	Porto Ricos, 3.55; Cubas, 3.58.
" 26	3.55	71.00	Cubas.
" 27	3.485	69.70	Philippines, 3.48; Cubas, 3.49.
" 28	3.52	70.40	Porto Ricos.
Mar. 3	3.491	69.83	Philippines, 3.52, 3.465, 3.49.
" 4	3.49	69.80	Porto Ricos.
" 5	3.52	70.40	Philippines, 3.49; Porto Ricos, 3.49, 3.55.
" 6	3.61	72.20	Porto Ricos, Philippines.
" 7	3.625	72.50	Cubas, 3.61; Philippines, 3.61, 3.64; Porto Ricos, 3.61.
" 8	3.67	73.40	Cubas.
" 10	3.64	72.80	Porto Ricos, 3.67; Philippines, 3.64; Cubas, 3.61.
" 11	3.61	72.20	Philippines.
" 12	3.623	72.46	Philippines, 3.64, 3.62; Porto Ricos, 3.61.
" 13	3.64	72.80	Cubas.
" 14	3.66	73.20	Porto Ricos, 3.67; Philippines, 3.65.
" 15	3.77	75.40	Cubas.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXIV. JULY, 1930 Number 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Molasses and Biological Soil Activity:

A study of the action of molasses in the soil shows it to be to a great extent biological. The sugars contained in the molasses disappear rapidly due to the growth of yeasts. In this process a large amount of living micro-organic tissue is built up and remains in the soil as such. Nitrate or inorganic nitrogen is changed to the organic form as protein in the yeast cells. Approximately 25 pounds of nitrogen is used per ton of molasses applied.

Forestry in Formosa:

A few paragraphs and photographs pertaining to the forestry problem in Formosa are presented. The article describes the forests, the amount of lumber obtained as well as a few species of trees that occur in the forests. The photographs give some idea of the trees and of the reforestation work that is being carried out by the Government.

Cane Diseases in Mauritius:

The salient points regarding cane diseases that occur in Mauritius are briefly summarized from the Annual Report of the Department of Agriculture of the Colony of Mauritius for the year 1928.

Leaf scald disease was recorded for the first time in Mauritius. Other interesting points are brought out on the following diseases: leaf scald, gumming disease, red rot, pineapple disease, smut, streak disease, root disease complex, pokkah boeng, eye spot, stem deterioration and the cane-killing weed.

Methods in Plant Physiology

An account is given of methods in plant physiology, utilizing sugar cane in water culture

Forestry on Oahu

A review is presented of ten years participation in forestry work on Oahu.

Pre-Harvest Sampling of Cane.

By courtesy of a committee of the Association of Hawaiian Sugar Technologists this issue presents a study of the pre-harvest sampling of cane by refractometer at Ewa Plantation Company, which indicates that the progress of cane ripening can be followed in a general way through pre-harvest sampling for the determination of solids only.

Modification of the Kjeldahl Method:

A modification of the standard method for the determination of Kjeldahl nitrogen saves much time without any sacrifice of accuracy. This modification consists of the substitution of boric acid for standard sulfuric acid as the absorbent of the ammonia. In this article the results of applying the new methods to the determination of nitrogen in fertilizers at this Station is discussed.

Decomposition of Carbohydrates in Water-logged Soils:

A review is presented of a recent paper dealing with the fermentation of sugar in water-logged or water-covered soils, the effect on fermentation of additional elements, the transitory effect in the soil, the various steps involved in the decomposition and the final products of such anaerobic decomposition of carbohydrates

Determination of Phosphoric Acid Colorimetrically:

A large number of determinations of phosphoric acid are made in the laboratory of the chemistry department. The standard method of analysis is slow and somewhat tedious. A colorimetric method is described which is rapid, accurate, and in many respects superior to the older method generally in vogue.

Studies on Plant and Water Relations in Hawaii.

That Hawaiian soils possess a more or less precise wilting coefficient, and that local soils are similar to those found elsewhere in that the residual moisture content at the time of wilt depends only upon the soil and not upon the sort of plant under observation, is suggested by the report of a series of experiments included in this issue.

Waipio soil in carefully sealed containers was planted to sunflowers and to buff beans. The residual soil moisture at the time of wilting was surprisingly similar. Although two species are too few to permit general conclusions they do provide some evidence that local soils are similar to mainland soils in the possession of a definite wilting coefficient. The percentage of soil-moisture at the time of wilt was remarkably high. Plants in the soil under observation showed real wilt at a moisture content greater than that contained in many mainland soils immediately after irrigation.

Difficulties were experienced when sugar cane plants were used as an indicator of wilt. Cane apparently does not wilt in the sense used in the literature of the subject. The leaves consistently regain turgidity after a given exposure to a saturated atmosphere, regardless of the soil-moisture content. However, physiological disturbances may be noted at the moisture content identified as the wilting coefficient by other plants. The most evident disturbance is a reduction in the rate of transpiration after the wilting coefficient has been reached. Studies since the completion of the original paper appearing in this issue indicate that elongation or growth is impossible when the soil moisture is below this critical constant.

This work is being continued and elaborated at Waipio.

Germination of Sugar Cane Pollen:

The germination of sugar cane pollen is dependent upon a nice balance of retroactive physical and chemical factors. Experiments are reported whereby an attempt is made to standardize a method of germinating sugar cane pollen *in vitro* in hanging drops of culture media by controlling the concentrations of sugar and agar and the pH values of the media, the relative humidity and the temperature of the air surrounding the hanging drops, and by addition of enzymes to the culture media.

Quantitative data are offered to show that, when a series of culture media having a gradient of viscosities due to increased concentrations of sugar and agar was used, one particular medium consistently gave the maximum percentage of germination. An optimum relative humidity and temperature were found. While there was a correlation between temperature and percentage of germination there also existed a correlation between percentage of germination and the difference between the temperature of the air when the pollen was shed and the temperature at which germination occurred. The addition of Taka-diastase to the culture media definitely increased the percentage of germination.

Methods in Plant Physiology

By H. L. Lyon and Hugh Brodie

The investigation of certain problems in the physiology of the sugar cane plant through the application of precise laboratory methods was a new line of work allotted to the department of botany and forestry at the beginning of the year 1929. In the few months that have elapsed since that time, all of our efforts in this particular field of research have been directed towards the development of a suitable technique, so we have as yet no contributions to the knowledge of the physiology of the sugar cane plant to offer. It seems, however, that one of our experiments being carried on in the open at the Experiment Station has attracted considerable attention and the present paper is written to satisfy numerous demands for a description of the technique employed.

We are striving to develop methods for the study of water consumption by the cane plant and the experiment in question represents one of the several methods which we are testing out. In this particular experiment, a plant was grown in water culture with its root system confined within a sealed container into which new solution was admitted from an outside reservoir to replace that withdrawn by the plant. By a system of automatic weighing and recording, the speed of water consumption was indicated on a chart.

The shape and construction of the container employed and the method of installing a cane plant therein is indicated in the diagram reproduced herewith as Fig. 1. This container is made in two parts: a cylindrical tank 21 inches deep by 12 inches in diameter with a flange on its rim and a conical cover, also flanged on its rim to match the flange on the tank. A tight seal between the cover and tank is secured by interposing a waxed gasket between their flanges and bringing these tightly together with bolts spaced about 1 inch apart. A tight seal about the stalk of cane in the neck of the container is secured by inserting a large rubber stopper, "R," accurately bored to fit the stalk. This is forced tightly into place and covered, first with a layer of wax and then with a poured plug of a cement made of litharge and glycerine, which is eventually coated over on its exposed surface with shellac. A socket, "S," centrally attached to the bottom of the tank serves to hold the base of the cane stalk in position in the container. Three tubes, "I," "A" and "O," through the cover serve as an inlet for solution, an outlet for air and solution and an avenue through which thermometers and other instruments may be lowered into the tank. These tanks are made of 24-gauge galvanized iron and the tubes are of brass. All exposed surfaces on the interior of the tank are coated with paraffine when it is about to be used.

A suitable cane plant for experiment is secured by selecting an average stalk from a stool in the field and causing it to throw out roots at the desired level by encasing this portion of the stalk in a jacket filled with sand, moss or sawdust, which is kept moist by adding water at frequent intervals. A portion of the inner tube of an automobile tire slipped on over the top of the shoot and tied up at its

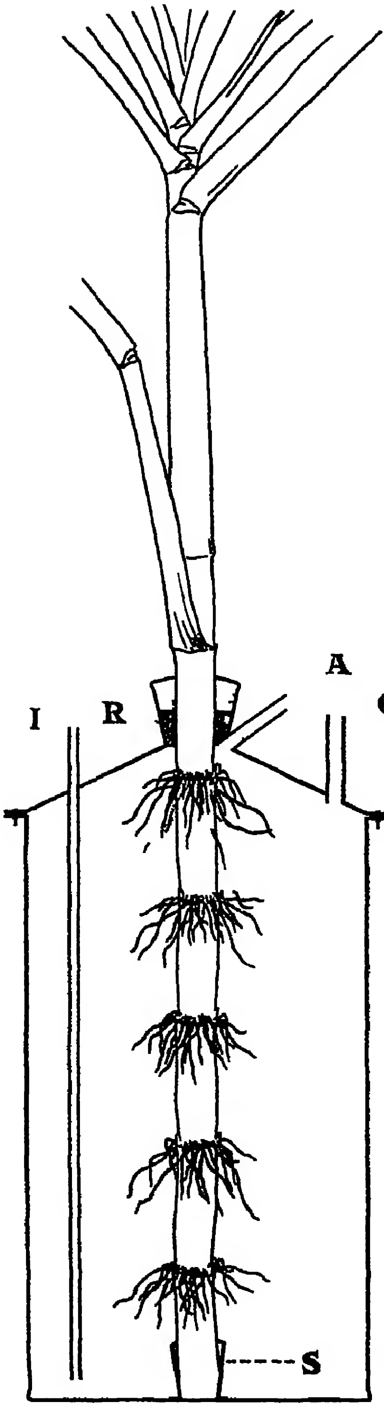


Fig 1 Diagram showing container in vertical section For description see text

Fig 2 Cane stalk encased in a piece of inner tube filled with moist sawdust to induce growth of roots Photo by E L Caum

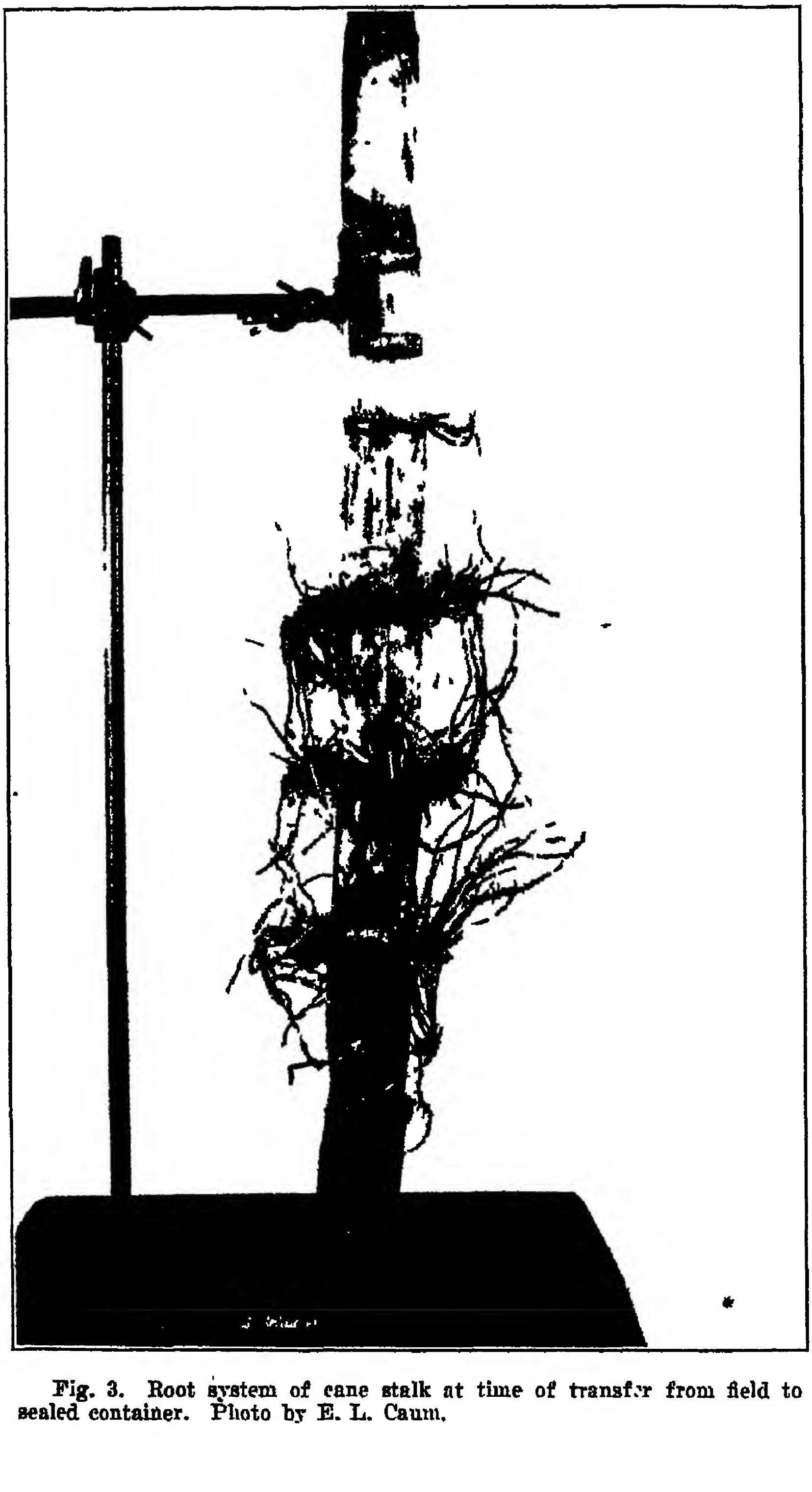


Fig. 3. Root system of cane stalk at time of transfer from field to sealed container. Photo by E. L. Caum.

Fig. 4. A cane plant which has been grown for nine months with its root system enclosed in a sealed tank, this tank standing in a larger container through which tap water is kept flowing to regulate the temperature. Photo by Twigg-Smith.

lower end in the manner indicated in Fig. 2 makes a very serviceable jacket. A cane stalk being treated in this manner is staked up to keep it from falling over under the added weight. When a cane stalk so jacketed has developed a goodly number of roots, it is cut off in an appropriate length and transferred to culture solution in a sealed container in the manner already indicated, the jacket and absorbent material being first removed. (See Fig. 3.) This method of transferring a fully developed cane shoot from a stool in the field to a water or soil culture is by no means new. Its employment in sugar cane breeding work has been well described and illustrated by Venkatraman and Thomas.*

While a cane plant is growing in a sealed tank as described above, the solution within the tank is held at a reasonably constant temperature by placing the tank within a larger container through which tap water is kept flowing at all times. By this means, variation in temperature may easily be kept within 2 degrees C. in any 24-hour period.

We have grown a cane plant in a tank of this sort for a period of 12 months and it made a growth quite equal to, if not better than, that displayed by the other shoots of the stool from which it was taken. This particular plant is illustrated in Fig. 4, the picture being taken when it was about 9 months old. The original shoot elongated quite as rapidly as did its sister shoots, which remained in the field, but in addition to this elongation, it threw out lalas at an early age which eventually developed into sticks of considerable size. At the proper season, this plant flowered in the normal manner and later elaborated a tassel in the top of one of its lalas. After removal from the stool in the field, this cane shoot received tap water only throughout the entire year in which it was growing in the tank. No salts whatsoever were added at any time, the plant extracting all of its nutrients from tap water which, at the Experiment Station, is from artesian wells.

The performance of this plant under the conditions to which it was subjected excited much interest and comment among observers and opinions were freely offered regarding the composition of the cane and the quality of its juices. When it had completed a full year's growth on tap water in tank culture, it was taken out and numerous analyses secured, the more interesting results being recorded in the accompanying tables. When the sealed container was opened, it was found to be packed full of roots which were interlaced into a compact mass that retained the shape of the container after it was withdrawn therefrom. The extent and condition of the root system are well illustrated in Figs. 5 and 6.

JUICES OF CANE GROWN IN TAP WATER

	Brix	Polarization	Purity	Quality Ratio
Main stalk	19.66	17.97	90.86	7.3
Lalas	19.17	17.46	91.08	7.49

Analyses by H. F. Bomonti

The Agricultural Journal of India 21:203 209, 1926.

Fig. 5. Root system of cane plant shown in Fig. 4 when removed from sealed container at end of twelve months. Photo by E. L. Caum.

Fig. 6. Same subject as Fig. 5 but with one half of root system cut away. Photo by E. L. Caum.

COMPOSITION OF CANE GROWN IN TAP WATER COMPARED WITH THAT OF CANES OF THE SAME VARIETY GROWN IN THE FIELD

Date of Sampling	Origin of Sample	Age Months	Part of Plant	Percentages Expressed on Dry Plant Substance				Percentages Calculated to Green Plant Basis				
				Organic Matter Sugar, etc.	Ash Per Cent	Silica SiO_2 Per Cent	Nitro. N Per Cent	Moist. Per Cent	Organic Matter Sugar, etc.	Ash Per Cent	Silica SiO_2 Per Cent	Nitro. N Per Cent
Mar. 12, 1930	H 109 from Transpiration Experiment at Experiment Station	12	Lala Leaves	91.0	9.01	4.84	.95	72.49	25.03	2.478	1.330	.261
			Lala Stalk	97.8	2.21	1.08	.69	71.16	28.20	.636	.311	.199
			Main Stalk	97.8	2.20	1.09	.43	71.12	28.25	.634	.315	.125
Jan. 13, 1930	H 109 from Oahu Sugar Co., Ltd., Field 49	22 (Est.)	Leaves and Tops	92.5	7.47	1.68	.88	80.03	18.48	1.492	.335	.176
			Stalks	99.1	.92	.17	.15	74.88	24.89	.231	.043	.038
Feb. 10, 1930	H 109 from Waimanalo Sugar Co. Field 175	12	Leaves and Tops	92.7	7.35	2.02	1.08	77.25	21.08	1.672	.460	.245
			Stalks	97.4	2.56	.19	.31	77.71	21.72	.571	.042	.070

Analyses by J. H. Duffy

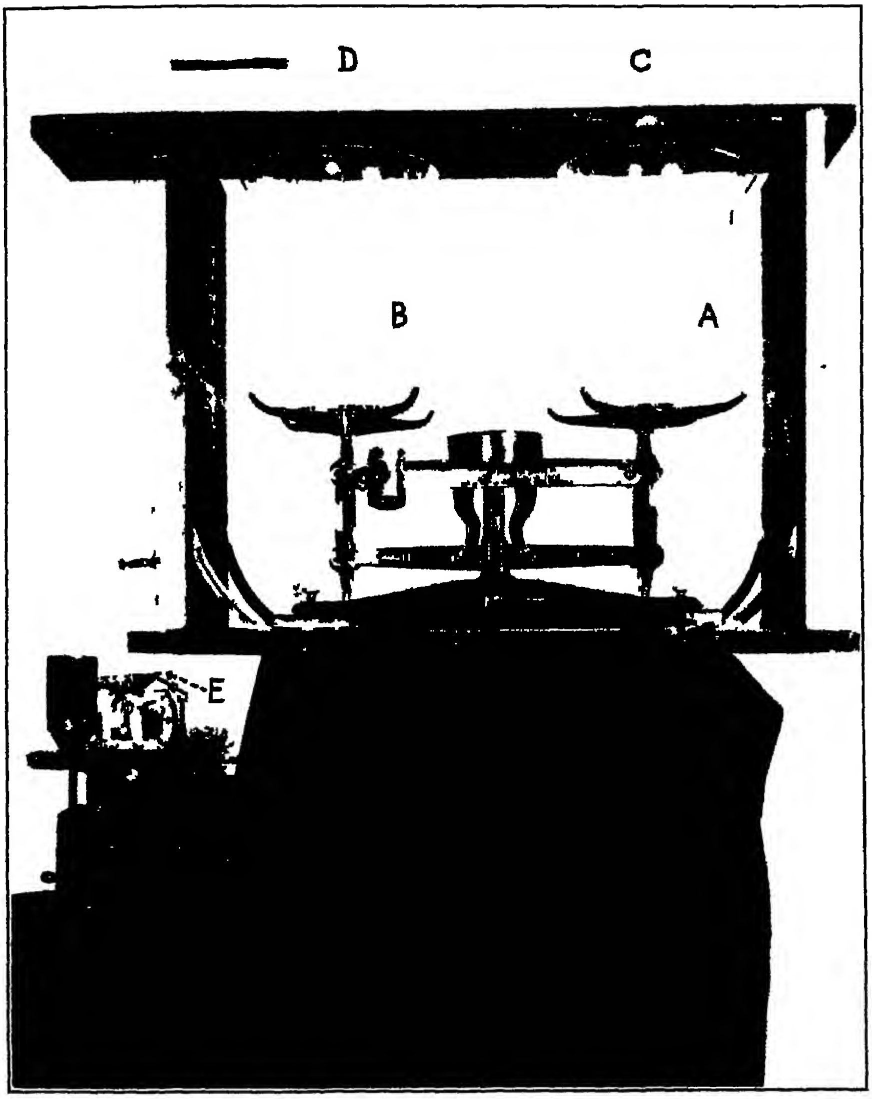


Fig. 7. Apparatus for the automatic weighing of water withdrawn from container by cane plant. For description see text. Photo by E. L. Caum.

As previously indicated, the sugar cane plant described and illustrated above was employed as a subject in the evolution of a technique for determining the rate of water consumption by a cane plant and we will now describe this technique in its present stage of development. During periods of observation, water extracted from the container by the plant is replaced from a reservoir through a rubber tube connecting with the brass inlet tube "I," shown in Fig. 1. The supply reservoir is held at a slight elevation above the culture tank so that a flow from the reservoir into the tank can be maintained by gravity.

Now, in preparing to take a reading on the rate of water consumption, tubes "A" and "O" are opened and water is allowed to flow into the tank through

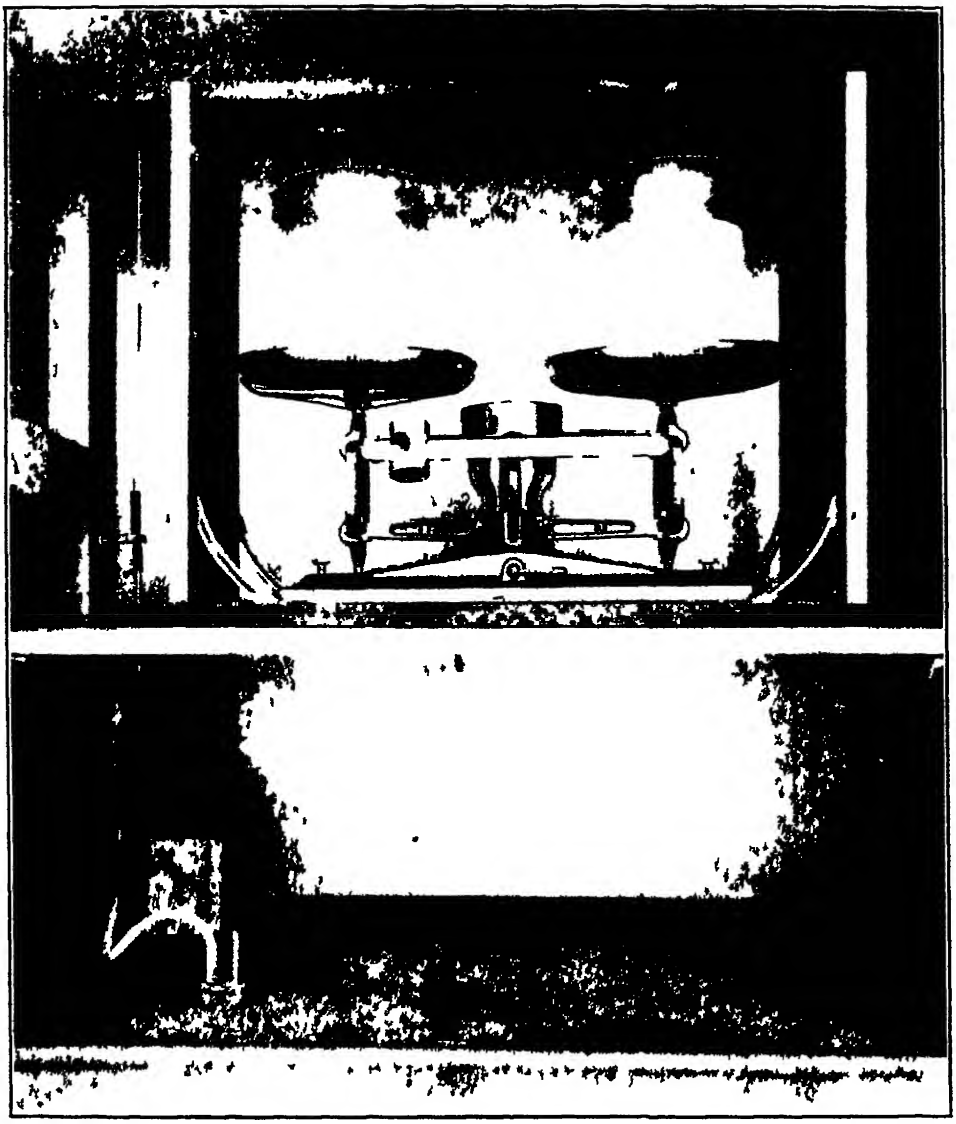


Fig. 8. Weighing apparatus installed in cabinet in the field. At the time the picture was taken, one siphon was closed and the balance was blocked to prevent movement.

tube "I." Such air as may be in the tank will be forced out through tube "A" and when water is flowing from "A" and "O," both of these tubes are securely closed with stoppers. From that time on, water passing in through "I" will represent that consumed by the plant, and the speed of water consumption is the speed of outflow from the supply reservoir. Our apparatus for measuring the flow of water from the reservoir into the tank is demonstrated in the set-up shown in Fig 7. Two beakers—"A" and "B"—of equal capacity and of approximately equal weight are placed upon a Torsion balance within a rack, as illustrated. Tubes "C" and "D," of equal size and supported by the rack, extend down nearly to the bottoms

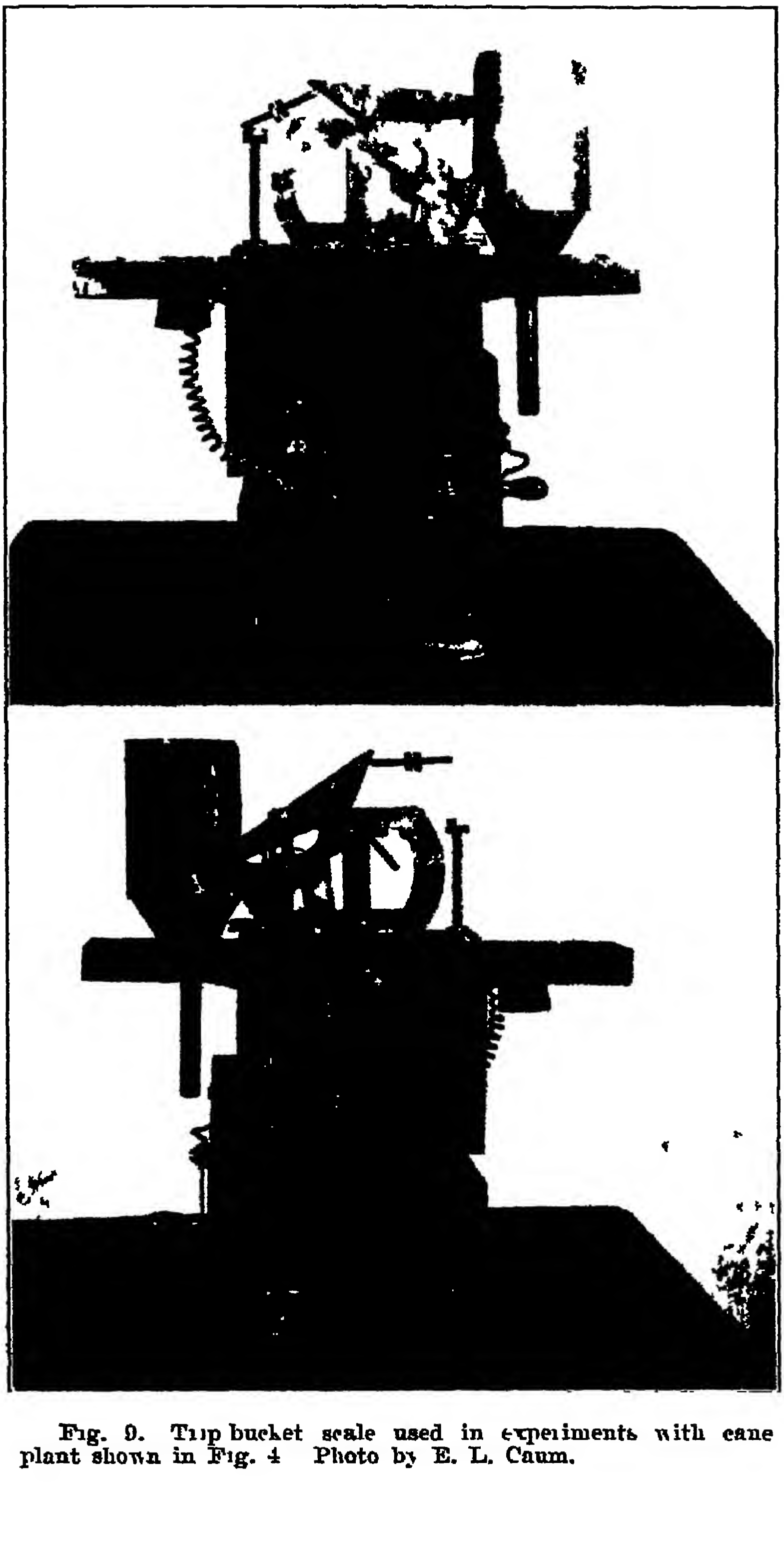


Fig. 9. Tip bucket scale used in experiments with cane plant shown in Fig. 4 Photo by E. L. Caum.

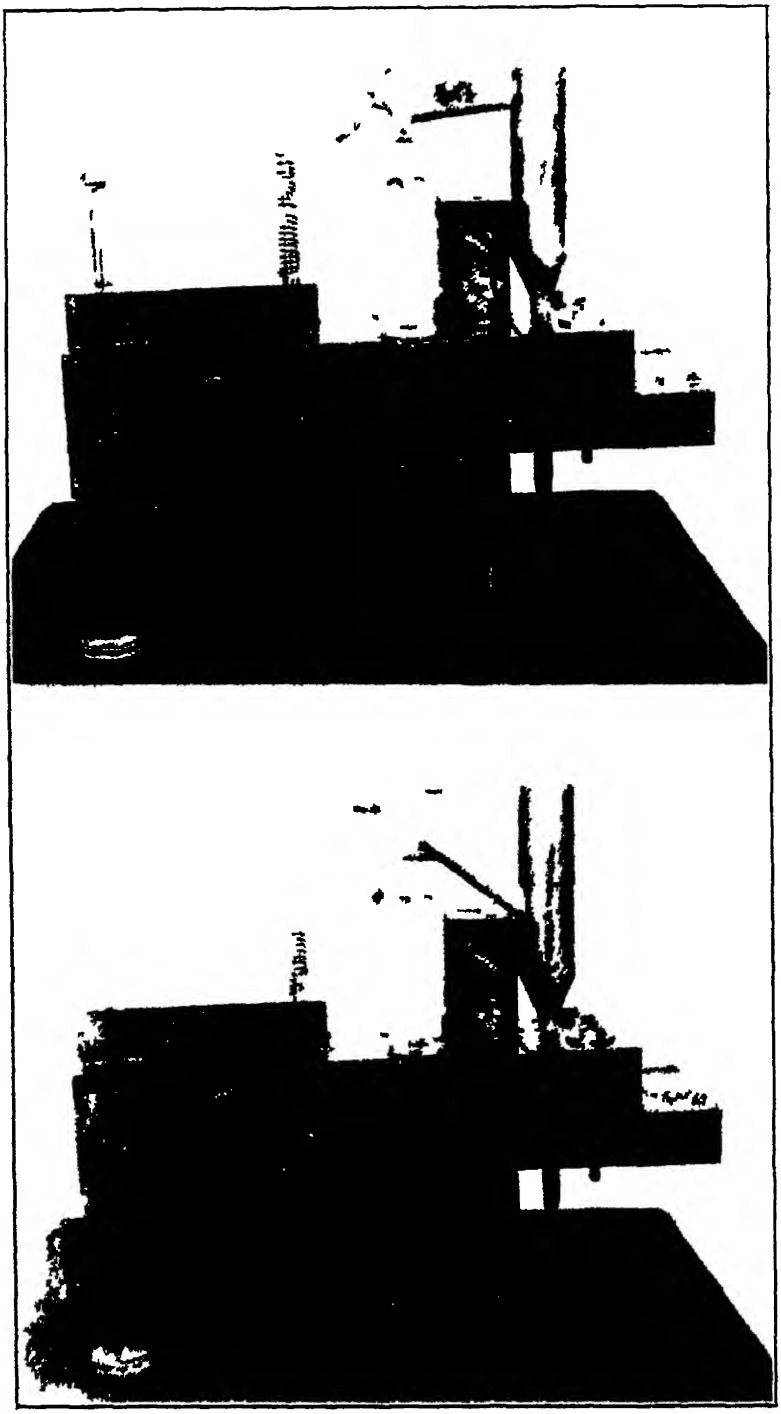


Fig 10. One of the tiip bucket scales now in use Photo by E L Caum.

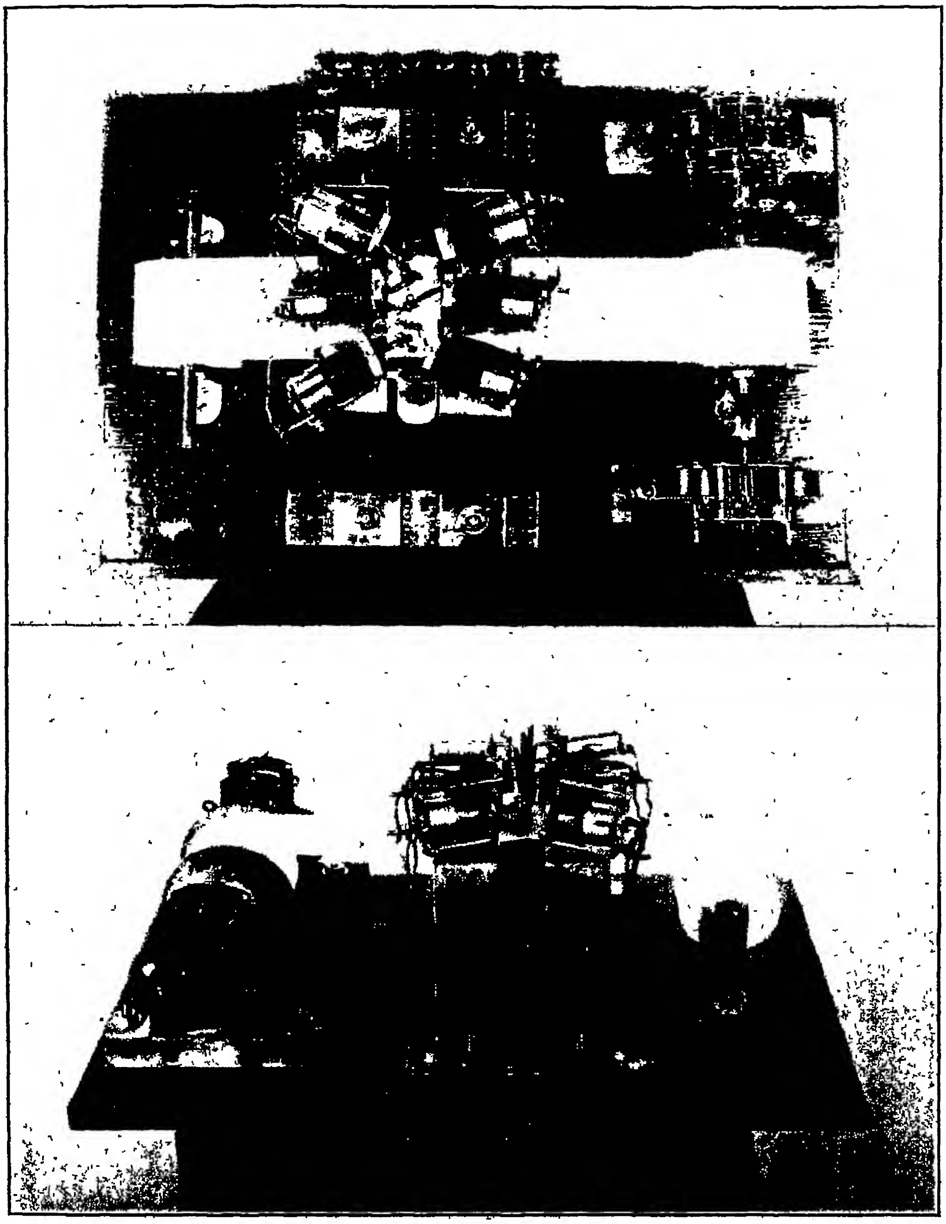


Fig. 11. Recording instrument with six circuits as seen from above and from one side. Photo by E. L. Caum.

of the beakers. A flat piece of rubber is cemented on the bottom of beaker "B" and the tube "D" is adjusted so that its lower end just touches, and is closed by, this rubber when the scale is balanced. Tube "C" is connected to the inlet tube "I" of the culture tank with rubber tubing. Tube "D" is extended with rubber and glass tubing, as indicated, so that it may serve as a siphon to withdraw water from beaker "B." To operate, beakers "A" and "B" are filled with water or culture solution and siphons are established from each through the tubes entering them

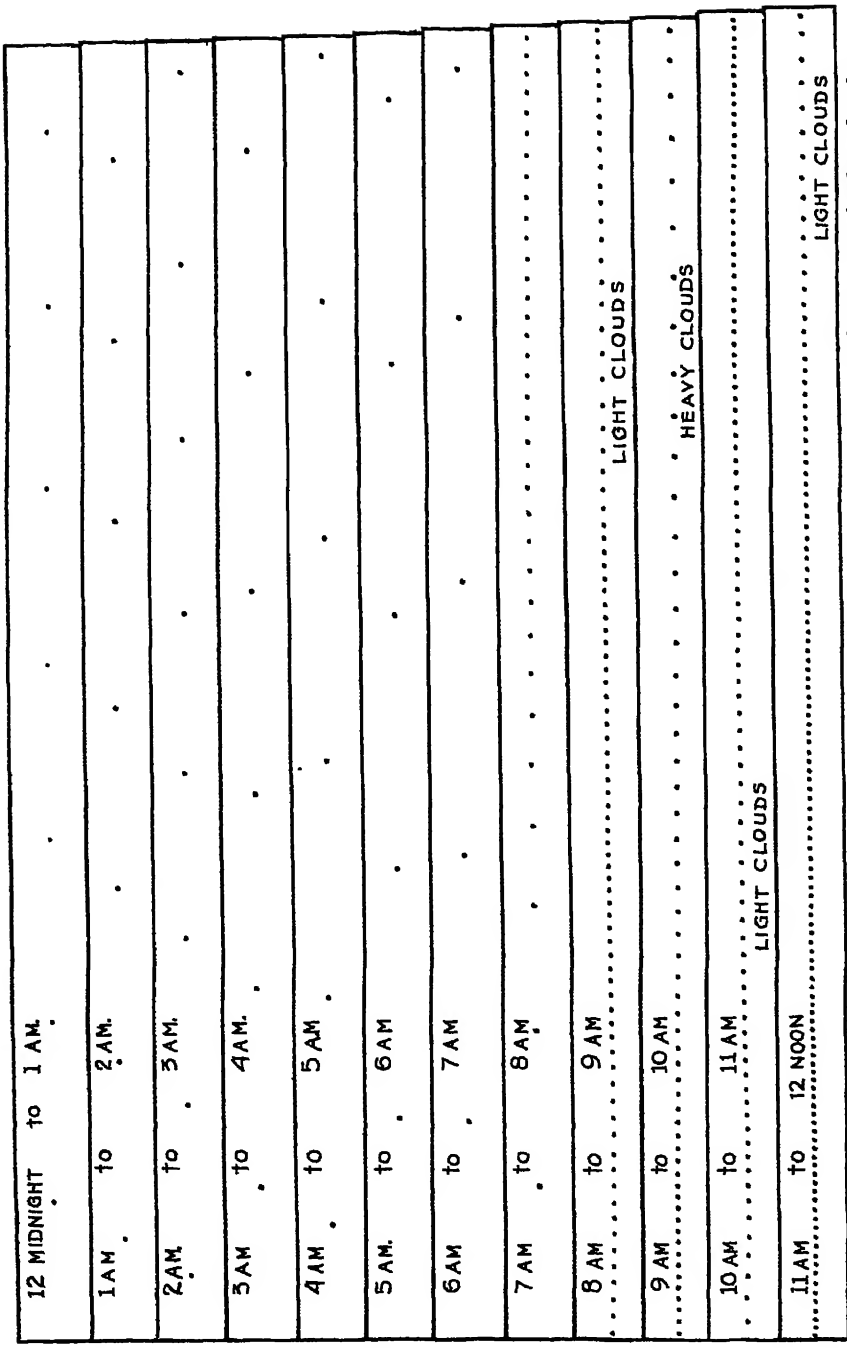


Fig. 12. Record of water withdrawn from container by the cane plant shown in Fig. 4 during a period of twelve hours. Each dot records a trip of the scale, which was adjusted to weigh 4 grams.

from above. Water withdrawn from the culture tank by the cane plant will be replaced from beaker "A" through siphon "C." This will render beaker "A" lighter than beaker "B," hence "A" will rise and "B" will fall. The falling of beaker "B" will remove the rubber from the end of tube "D" and water will flow through this siphon until "B" rises sufficiently to close the opening of tube "D."

Thus, as the cane plant extracts water from beaker "A," an equal amount is automatically discharged from beaker "B"

When we designed this apparatus, we expected that the discharge through siphon "D" would be in periodic spurts, but in operation we find that the discharge is remarkably uniform The tubes "C" and "D" affect the weight of "A" and "B" equal to that of the water which they displace and when beaker "A" rises, more of tube "C" and less of tube "D" are submerged and consequently these tubes act as a damper and temper the swing of the balance.

A trip-bucket scale, "E," is so placed that it will weigh the water discharged from siphon "D." This scale is adjustable so that it can be made to trip at any desired weight between 0.5 and 6.0 grams. The bucket discharges through a funnel into a container and the accumulated water is weighed to check the record of the scale. Every time the scale trips, it closes an electric circuit, causing a pencil to make a dot on a moving strip of paper.

In Fig. 7, the essential parts of our weighing apparatus are posed so as to show the arrangement of parts, but when in use, this apparatus is enclosed in a tight and rigid cabinet which is supported upon concrete posts, set deeply into the ground Such a cabinet may be seen beside the cane plant in Fig. 4. The installation of the apparatus within the cabinet may be seen in Fig. 8. As beakers of equal size are used, the loss by evaporation is the same from each beaker, but as the entire apparatus is enclosed within a cabinet which is practically air-tight, the atmosphere soon becomes saturated, so evaporation does not cause an appreciable error in our results. The development of a satisfactory trip-bucket scale has required considerable experimentation. The one used for obtaining records from the plant shown in Fig. 4 is illustrated in Fig. 9. A model which we are now using is illustrated in Fig. 10. In our earlier models, the electric current was passed through the axle, but arcing injured the bearings and we have employed other channels for the circuit: in the instruments now in use, two platinum wires on the underside of the bucket dip into two mercury cups and close the circuit. The trip buckets are made of thin copper and, after fabrication, are electroplated with silver.

In the recording instrument employed in our experiments (Fig. 11), paper tape is rolled off from one drum onto another, passing in transit over a small block or table. Recording pencils are poised over this table and whenever current passes through a coil controlling a pencil, this pencil descends, making a dot on the paper tape. One recording pencil is employed to mark the time on the tape. A simple attachment on a clock serves to close a circuit at desired intervals and these intervals are indicated by dots on the tape. In our experiments, we are using 15-minute intervals, but any other interval desired may be as easily employed. A record of water consumption by the cane plant shown in Fig. 4 through a period of 12 hours is reproduced herewith as Fig. 12.

One important matter that must be considered in conducting experiments of the nature described above is the proper aeration of the water or culture medium about the root system of the plant. Continuous records of the water extracted from the sealed container by the cane plant shown in Fig. 4 were usually made through periods of 24 hours, although a few records obtained cover 48-hour periods. During the intervals when records were not being taken, a gentle flow of tap water was maintained through the container and this provided the necessary aeration.

Cane Diseases in Mauritius

By J. P. Martin

In the Annual Report of the Department of Agriculture of the Colony of Mauritius for the year 1928 there appeared several interesting paragraphs pertaining to sugar cane diseases. The salient points in these paragraphs may be briefly summarized as follows:

Leaf Scald

This disease was recorded for the first time during the year (1928) but undoubtedly had existed for many years and had been confused with gummosis or gumming disease of sugar cane. Leaf scald is now known to be widespread over the island. It attacks chiefly White Tanna and Striped Tanna canes and results in losses both in the field and factory. Experiments have been conducted wherein losses of from 5 to 11 per cent of cane weight occurred and the sucrose content reduced as much as 16 per cent. White Tanna is tolerant to the disease and fair yields are still being obtained under favorable climatic and cultural conditions. The disease affects not only the standing cane but greatly inhibits the germination of cuttings and the ratooning qualities.

The methods of control are the substitution of resistant varieties when feasible, the disinfection of cuttings (the method of disinfection is not given) and the selection of healthy cuttings for commercial propagation.

Gumming Disease

Gumming disease is similar to leaf scald in that it causes a loss of cane weight and sucrose content. It also seriously affects the germination of cuttings and retards the ratooning qualities of stools. No varieties are immune, but some offer a high degree of resistance to the disease. White Tanna is widely affected but, with this variety, the losses are less than they are in the case of leaf scald disease. M. (Mauritius) 55 and 131 manifest heavy leaf infection from gumming but little stem infection. D. K. 74 and R. P. 8 are highly resistant to both leaf scald and gumming. Two other local seedlings, M. 2316 and M. 2716, also exhibit a high degree of resistance to gumming disease.

Leaf scald and gumming exhibit somewhat similar leaf symptoms during certain periods of their development and are at times listed together during plantation surveys. Injuries from these two diseases were slightly less in 1928 than in 1927. In both diseases leaf infection causes much smaller losses than stem infection.

Measures recommended for the control of gumming are: the selection of healthy planting material, the establishment of nurseries with healthy cuttings from which a supply of healthy cuttings for plantations may be secured, and the replacement of susceptible varieties by more resistant ones. New seedlings that prove to be highly susceptible to gumming are immediately eliminated.

The results of preliminary experiments regarding the control of the two diseases by the so-called "hot water treatment" are interesting. In the majority of cases immersion of cuttings in water at 60° C for 15 minutes killed the buds. Healthy cuttings of White Tanna and cuttings affected with leaf scald and with gumming were immersed in water at 50° C for one hour and at 55° C. for one-half hour. Similar lots of cuttings were planted without the hot water treatment. The experiment is not sufficiently advanced to indicate definite conclusions, but in most cases the treatment for one hour at 50° C. stimulated germination. Both healthy and leaf-scald-affected cuttings withstood the treatment at 55 C for one-half hour and showed a high percentage of germination. The cuttings affected with gumming disease and treated at 55° C for one-half hour showed a low percentage of germination.

Red Rot

Of the varieties White Tanna, D. K. 74, M 131 and M. 55, the D. K. 74 was most susceptible to red rot disease. White Tanna was highly resistant to red rot. A serious outbreak of red rot occurred on R. P. 6 on one estate. In certain localities the disease was severe but in general the losses in 1928 were less than in 1927.

Pineapple Disease

Losses from pineapple disease are manifested through the failure of cuttings to germinate or in the stunting of young shoots, especially in regions where dry weather generally prevails.

Smut

"Caused by *Ustilago scitamineae*, is still almost confined to the drier regions of the island."

Streak Disease

Streak disease is confined to R. P. 8 and was rarely encountered during the year. Losses from this disease were negligible.

Root Disease Complex

Instances of the root disease complex, the exact cause of which is still obscure, were reported from widely separated areas. A disease which produces a wilt and causes mature canes to die rapidly is at present included under the heading of root disease complex and seems to be parasitic in its origin.

Pokkah Boeng

The condition recognized as pokkah boeng in Java and in other cane-growing countries was recorded during the year. The condition seems to be associated in some rare cases with a heart or top rot. Losses from the disease were small.

Eye Spot

Heavy attacks of eye spot on leaves of White Tanna were encountered on a few estates during the wet season of April. No losses from eye spot disease were reported.

Stem Deterioration

This trouble is widespread, especially on White Tanna and Striped Tanna canes. It is manifested "by a dry, white, pithy deterioration in the center of the stem which later turns red to reddish-brown with yellow patches on either side of the affected stem. Later the center of the stem becomes hollow. The condition is not regarded at present as being parasitic in its origin. Bacteria have been isolated from affected tissues, but they were not proved to be parasitic." Further investigations are being conducted on this trouble.

The Cane-Killing Weed

A rather severe attack of *Striga hirsuta*, which is a flowering parasitic plant affecting sugar cane roots, was observed on one estate.

Cane affected with this parasitic weed is stunted and the whole plant has a withered appearance. The parasite may be found growing near the base of the affected stool.

Forestry on Oahu

By George A. McEldowney

This Unit was organized in 1919 under the supervision of the department of botany and forestry, to cooperate with the officers of the Board of Agriculture and Forestry in promoting forestry work on the island of Oahu. The results sought through the work to be undertaken by this Unit were to protect and increase the forest cover on the watersheds of Oahu so as to conserve the water falling thereon and divert it into useful channels.

Reconnaissance

The first work undertaken by this Unit was to gather all available information concerning the lands on this island, their boundaries, ownerships, topography and appropriate classification as forest lands, agricultural lands, grazing lands and waste lands. Much time was spent in consulting authorities, maps and land records, and all data obtained were checked in the field. A series of indexed maps was next prepared, setting forth this data in graphic form. These maps have proved invaluable to us in every phase of our later work. This is particularly true of the maps showing (1) boundaries, ownerships and leaseholds; (2) classification of lands according to their most appropriate uses; and (3) the nature of the cover on forested lands and the extent of lands that should be reforested.

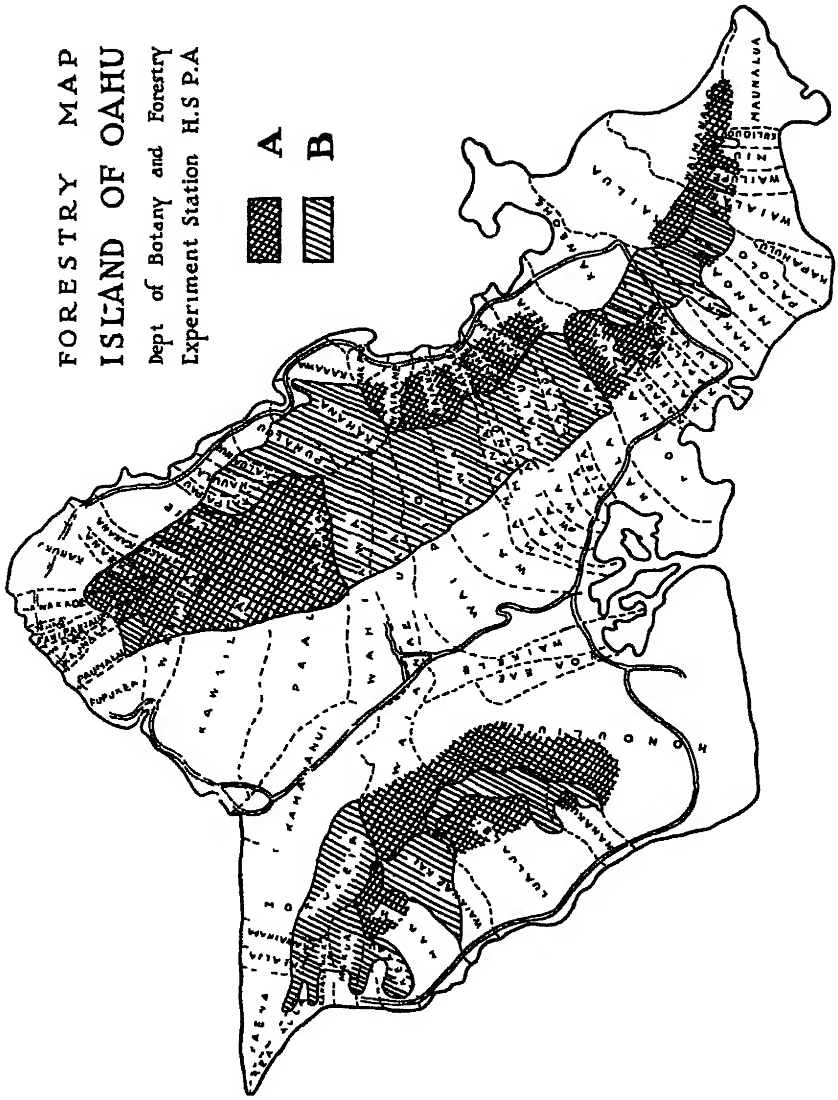
Forest Reserves Increased

When Unit No. 2 was organized in 1919, 67,333 acres of land on Oahu had been designated as "Forest Reserves" (areas shown in the light shading on Map 1). It was at once apparent that these reserves did not include some of the most important watershed areas on this island and our investigations showed that a very considerable part of these watershed areas not in reserves were being devastated by grazing animals; in fact, they were being heavily stocked as ranch lands and, being privately owned, were not subject to governmental control.

It was obvious that forestry work on Oahu would be more or less futile until additional large areas of watershed were set aside and protected as forest reserves. We presented these facts as clearly as possible and soon public sentiment was aroused to the extent that means were found for acquiring control of the land and putting it into forest reserves under the jurisdiction of the Board of Agriculture and Forestry.

Since the organization of Unit No. 2, 52,844 acres of land on Oahu have been added to the forest reserves (areas shown in dark shading on Map 1), making a total of 120,177 acres, or 31 per cent of the entire island. This, we believe, is pretty close to the maximum amount of land that can reasonably be set aside and administered as forest reserves on this island.

In the reorganization of the forest reserves of Oahu, it was necessary to run



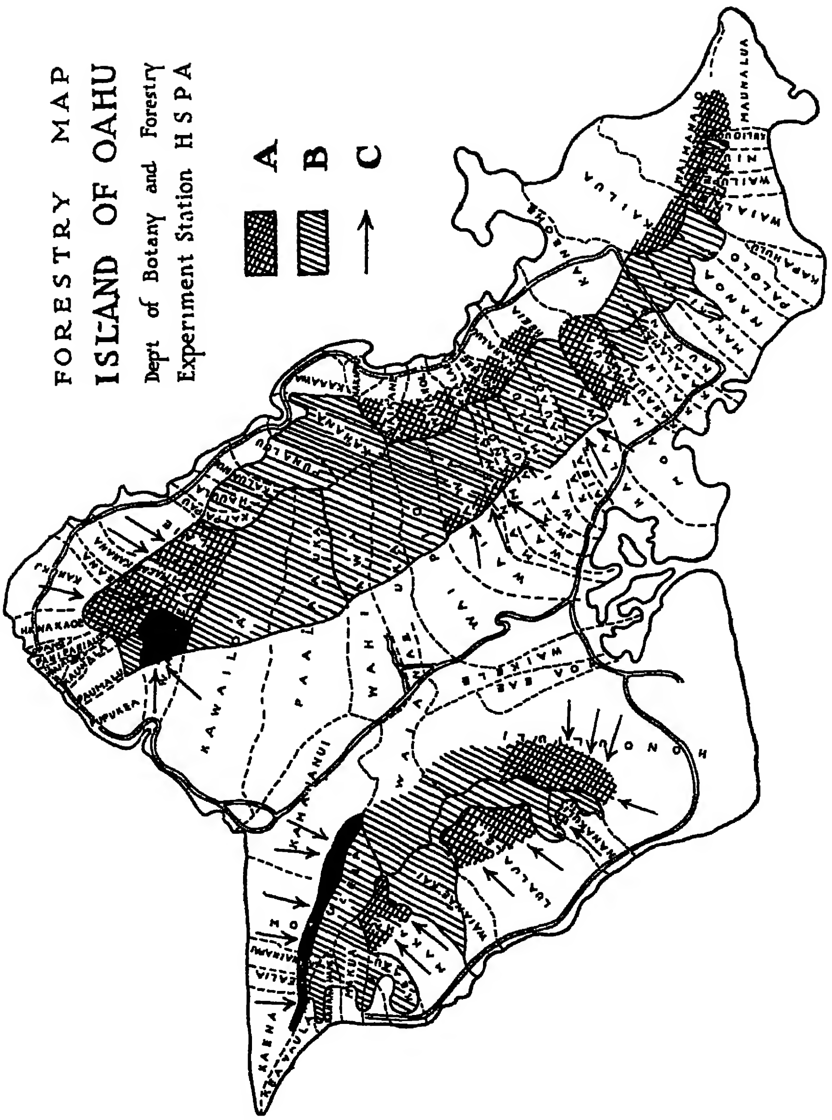
Map 1

A—Areas in Forest Reserves in 1919 67,333 acres
B—Areas added to Forest Reserves during past 10 years 52,844 acres

Total area in Forest Reserves in 1929 120,177 acres

boundaries in the field, not only around the new areas, but around all the old reserves, as many of the lines established in the earlier proclamations were not judiciously placed or were inadequately marked in the field. The running of these new boundary lines was done under the personal supervision of C. S. Judd. We accompanied him in the field and assisted in the marking of all courses. Our maps, previously prepared, proved of inestimable value in carrying out this work.

As soon as forest reserve boundaries were marked in the field and properly surveyed, the officers of the Board of Agriculture and Forestry undertook the construction of new fences and the rehabilitation of old fences along all boundary lines which were exposed to grazing animals. Some of these lines extended across very rugged country and presented serious obstacles for the fencers to overcome.



Map 2

A—Former ranch lands, now Forest Reserve, from which stock has been excluded during past 10 years.
B—Forest Reserve lands on which stock is still allowed to run.
C—Cattle adjacent to Reserve.

Great credit is due the Board of Agriculture and Forestry for the speed with which they completed very substantial fences of durable materials along all boundary lines where fences were required. Following the completion of the fences, the removal of roving stock was undertaken and we believe that, at this time, very few horses and cattle are to be found roaming within the forest reserves on this island.

Forest Plantings

At no time since its inception has this Unit been in position to make a record in tree planting. In fact, during the early years of its existence, we were instructed to go slow with planting operations and concentrate our energies upon reconnaissance, mapping and the collecting of data showing the necessity of placing such areas as

Honouliuli and Kahuku watersheds in forest reserves. Despite this handicap, Unit No. 2 has been responsible for the planting of 786,320 trees on Oahu since 1921. Some 503,000 of these trees have been planted in forest reserves or on watershed lands directly adjacent thereto. Plantations have planted about 157,000 trees on barren or waste lands outside the reserves for forest cover or commercial timber. Approximately 124,000 trees have been supplied for camp, park and roadside plantings.

The United States Army at Schofield Barracks has shown great interest in reforestation and has done some excellent work along this line, making very extensive plantings.

Most of the tree planting within forest reserves done by the Unit has been in the nature of experiments to determine suitable trees for employment under the conditions, and at the elevations, presented by the denuded areas within our foerst reserves. Ten years ago, eucalyptus and silver oak were about the only exotic trees known which could be grown to advantage within our forest reserves.

Forest Unit No. 2 made its first experimental planting in May, 1921. The area planted is located on the slopes of Kaukonahua Gulch above Wahiawa. All the varieties of trees then available in the Honolulu Nursery were planted in this experiment. The majority of these failed to make satisfactory growth under the conditions offered, but this experiment demonstrated that the paper-bark tree, *Melaleuca leucadendron;* the Formosan koa, *Acacia confusa;* and the Norfolk Island Pine, *Araucaria excelsa,* were admirably suited for planting within the forest reserves on Oahu. This experiment served to bring these trees to light for the first time and demonstrate their superior qualities. The conclusions reached from this experiment have been verified by later plantings and these three trees are bound to become important components of the future forests of this island.

The production of groves of fig trees at intervals within our forest reserves has been a definite part of our plan throughout all our forest plantings. We have obtained good stands of *Ficus macrophylla, Ficus rubiginosa, Ficus glomerata* and *Ficus nota.* We have shown photographs of some of these in our former reports, but the trees have now grown so large and mingled to such an extent with the native vegetation that it would be difficult to show them in photographs unless we made extensive clearings.

The wasps associated with the two species of figs first named above are now found on all parts of the island where these trees occur. These tiny wasps have made their way, unaided, all the way to Laie from Honolulu and always appear to be on hand at the first fruiting of a new tree. Results attained through the scattering of the seed of these trees by birds which have eaten the fruit should be noted within the next few years.

Planting Seeds

We have obtained very good results from planting seeds directly in the ground. We have employed the seeds of many different species of trees in experiments of this sort and believe that in the case of some species, we obtain better results from seed-spotting in the field than we do from setting out seedlings which were grown in the nursery. This is particularly true of trees that produce a tap root.

We have also obtained good results from *Ficus* seed thrown by hand onto stumps and logs along the trails within the forest. The favorable results obtained from seed spotting and broadcasting has led to the sowing of seeds from airplanes. The employment of this method of seed distribution has been made possible through the cooperation of the United States Army. On numerous occasions, they have supplied the airplane to distribute seeds over areas of our forest reserves which we have designated. In recent months, the Air Service, U. S. Army, at Wheeler Field, has made eleven trips into the air with its large Fokker plane in order to scatter quantities of tree seed for us.

We are often asked if any trees have grown as the result of this airplane sowing. We have always answered this question cautiously. We have numerous trees now growing from seed which was scattered by hand along forest trails. When we find a tree growing in the vicinity of a forest trail, we cannot be sure whether it is from seed sown from an airplane or from the trail by hand. It would be a difficult matter to locate one of these trees from a trail and a good deal of our airplane sowing has been done over areas not easily reached from a trail. One should consider that an airplane flying 800 feet or more above the ground, traveling 100 miles an hour, with its propellers whirling, must scatter the seed far and wide. It would be difficult to locate the seeds that sprout in a rough, partly wooded country unless one happened to stumble directly upon them. If, at the same time we made our first sowings from an airplane, fig seeds had been planted in the open and given the best of care, the resulting trees would not now be over 10 feet tall. A tree of that size could not be easily spotted at any considerable distance in our forests. We do not expect every seed we scatter to grow. Nature does not achieve that, so the trees resulting from our airplane sowings would probably be few and far between in any given area. They should suffice, however, to infect the locality with the tree in question and produce a focus from which it would later spread.

In recent months, we have found a fine specimen of *Ficus macrophylla* growing on an old koa stump in a deep gulch, far away from any forest trail, but in an area covered by our first sowing from an airplane. There can be little doubt but that this tree is a result of airplane seeding.

Arboretums

The Unit maintains two charted arboretums, one of 15 acres in the old townsite park at Wahiawa, which is now a forest reserve; and the other at Poamoho, which is also in the Wahiawa district. This latter arboretum is at 1,400 feet elevation and now includes about 20 acres, but can be extended at will, as it is inside the forest reserve. In this arboretum, we test out all trees available for forest planting under actual forest conditions. If they make favorable growth here, we plant them elsewhere within the reserves, but if they do not grow, we take them out and plant other trees in their stead. At this arboretum, we now have thirty varieties of our latest introductions under observation.

Wahiawa Nursery

Unit No. 2 organized a forest tree nursery some six years ago at Wahiawa. This nursery now covers 5 acres of land in the old townsite park, adjacent to our

Wahiawa Arboretum. We use this land, rent free, and the Wahiawa Water Company supplies us with water, gratis The soil is excellent and the situation is ideal for our purpose The elevation is 1,100 feet and the seedlings of many forest trees grow better here than they do in the nursery at Honolulu.

In addition to serving as a suitable place for growing tree seedlings, this nursery affords storage space in which seedlings grown at the Honolulu Nursery are held, sorted and distributed to various points on the island for planting Since its opening, there has been distributed from this nursery an average of 800 trees a month. One man makes his headquarters at the Wahiawa Nursery but attends to planting details at the Poamoho Arboretum and at other points within the forest reserve in addition to looking after the nursery stock and the distribution of trees.

Plantings on Plantation Lands

We have frequent calls from plantations for assistance in making camp, park and roadside plantings. To meet this demand, we grow and supply a large variety of shade, ornamental, fruit and nut trees. Although this is not strictly forestry work, it is, nevertheless, an important function of the Unit and one which we are pleased to perform to the best of our ability.

Several plantations have made rather extensive plantings of trees on their waste lands with the idea that these may be used at some future time for fence posts, firewood, railroad ties, etc. One plantation now has a 500-acre forest of eucalyptus trees including many of the better-known species. These trees were planted out only 16 years ago but the plantation is now taking from this grove each year some 1,200 cords of firewood, 100 cords of ditch posts, 87 cords of fence posts and 8 cords of car stakes. As yet, they are harvesting only *Eucalyptus robusta* and *Eucalyptus globulus*. Some of the better varieties, when full-grown, should yield very valuable timber. One of the public service corporations in these islands now sends to the mainland $25,000 a year for poles alone It has been demonstrated that poles, to meet their requirements, can be grown in these islands in from 15 to 20 years

Wild Animals in Forest Reserves

As noted in a previous paragraph, roaming cattle and horses have been practically eliminated from the forest reserves on Oahu through the efforts of the Board of Agriculture and Forestry. It is now difficult to find traces of cattle at any points within the reserves along the southern slopes of the Koolau Range. On the windward side of the Koolau Range and in some parts of the Waianae Mountains, cattle still invade areas that should be protected. Wild goats are now making their last stand in inaccessible parts of the Waianae Range. They are so closely and constantly watched by hunters that they will never be able to multiply to such an extent as to become a menace to our forests. Wild cattle and goats have been brought under satisfactory control but the wild hog had increased to such an extent that it is as serious a menace to our forests as either of the other animals has ever been. They eat seed and young seedlings, preventing natural reforestation, and they root up, and destroy, ferns and all other types of undergrowth.

They dig up the soil over large areas and rapid water erosion follows. The damage which they are causing is enormous and it is most serious because it is in the very interior of our forest reserves

Many pigs are being killed by hunters, but the operations of the hunters simply drive the majority of the pigs into the recesses of the forest where the hunters will not pursue them. Wild pigs will never be eliminated from Oahu forest reserves by casual hunters who pursue them merely for sport or the meat which they supply Our experiments in trapping pigs have given encouraging results and we believe this method of procedure offers the greatest promise of bringing about their ultimate eradication. The control of wild pigs is one of the most serious forestry problems of Oahu.

Firebreaks

The uluhi fern, which extends in an almost unbroken blanket throughout the length of the Koolau Range in the makai portions of the forest reserves, presents a fire menace that should receive serious attention. Should a fire get started in this fern during one of our periodic dry spells, it would be apt to travel far and do great damage before it could be brought under control with conditions as they are at the present time.

We believe that insurance against such a catastrophe should be obtained by building firebreaks through this fern blanket from makai, mauka along some of the prominent ridges. These firebreaks would prove a satisfactory line of defense against any fire that might get started and they would also afford an easily traveled avenue along which men could be moved to get at any fire that might get started in the interior of a forest reserve.

The great value of a firebreak has been demonstrated on several occasions by the very efficient one which has been built and maintained by the U. S. Army, at our suggestion, on the Waianae Range back of Schofield Barracks. It has not only stopped fires but has served as a trail along which fire fighters could quickly get to any danger point. We believe that the building of several firebreaks on the Koolau Range by Unit No. 2 would be a very valuable contribution to the cause of forestry on Oahu.

Control of Erosion

There are large areas of land within, or along the margins of, forest reserves in which we are particularly interested on which serious and rapid erosion is taking place. Heavy stocking and temporary cultivation are the factors which started the erosion in most cases and with the surface of the soil once broken, rain and wind are rapidly eating it away, leaving enormous earth scars, which are constantly growing in size and ugliness.

We have undertaken extensive experiments designed to find a means of stopping erosion and covering the scars with vegetation. Some degree of success has been obtained in several ventures, but we believe that a coarse grass which will act as a binder is going to prove the best plant to use as the first stage in this reclamation work.

Rain Gauges

In studying the rainfall records of Oahu and the data on which these records were based, it became evident that authentic readings must be made at additional stations before one could arrive at an approximately accurate estimate of the annual rainfall of this island.

An inventory of the existing rain gauges was made and it developed that the gauges were being read at ninety stations on the watersheds surrounding the Pearl Harbor Basin. The locations of the existing stations were plotted on a map and it was found that at least twelve additional stations must be maintained before we would be able to gather the required data. Up to the present time, gauges have been installed by Unit No. 2 at eleven of these stations and readings are taken at regular intervals. The installation of these gauges and their readings has required the building and maintenance of many miles of trail. It takes 12 hours of hard tramping to get a reading from one of these gauges. Our gauges are made of copper, according to specifications supplied by the Honolulu Sewer and Water Commission, and they record up to 26 inches of rainfall.

Through the cooperation of the Honolulu Plantation Company, Waiahole Water Company, Oahu Sugar Company, Waialua Agricultural Company and the Hawaiian Pineapple Company, readings of these gauges are made at regular intervals by trained observers. Records are kept on file at our office in Honolulu and are also supplied to the office of the U. S. Weather Bureau in Honolulu.

Future Work of Unit No. 2

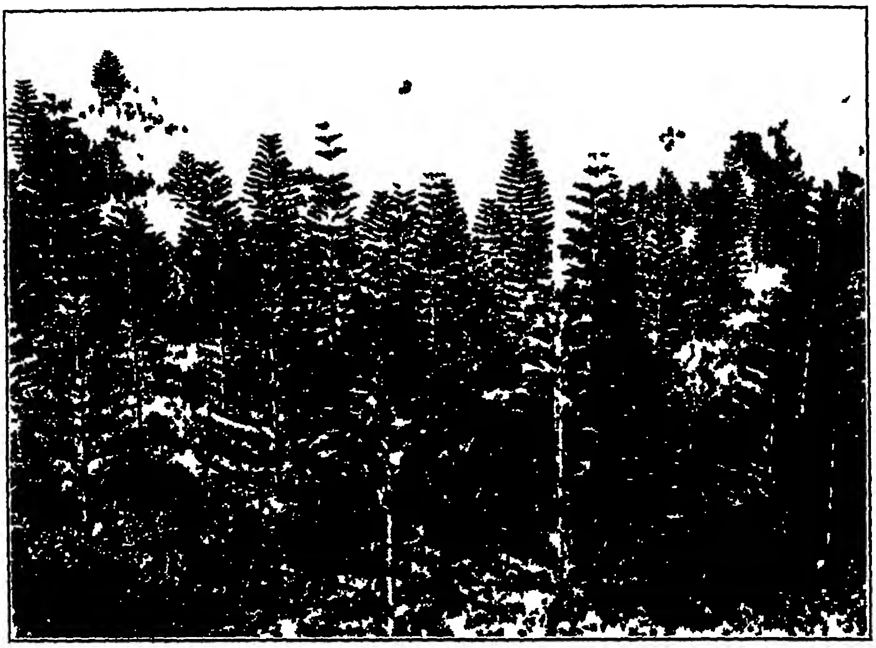
There is considerable public sentiment, which has found expression in several ways, that this Unit should confine its attention to problems which must be solved by experiment and leave the routine planting of trees within the forest reserves to the Board of Agriculture and Forestry. This would seem to be an appropriate arrangement, as the Board has ample funds to do as much tree planting as expediency requires.

We believe, however, that the Unit should continue work along all of the lines in which it is now engaged. These may be enumerated as follows:

1. Maintaining a forest nursery at Wahiawa for the distribution of trees.
2. Testing new trees in arboretums for the detection of desirable species.
3. Making small experimental plantings at intervals throughout the forest reserves in which we are most interested.
4. Conducting experiments in the control of wild pigs.
5. Conducting experiments in the control of soil erosion.
6. Securing and recording rainfall data.
7. Cooperating with plantations in the planting of commercial timber.
8. Cooperating with plantations in making camp, park, roadside and waste-land plantings.
9. Cooperating with the U. S. Army in making plantings on Army lands.
10. Cooperating with the Air Service of the U. S. Army in the planting of tree seeds from airplanes.

If the Board of Agriculture and Forestry will sanction the construction of firebreaks, we believe that the Unit should undertake this work as a new project. To build an appropriate firebreak, a trail should first be constructed along the crest of a ridge The uluhi fern should then be cut away for a considerable distance on either side of this trail and the cleared space planted up with non-inflammable trees and shrubs. Operations of this sort would supply not only protection against the spread of fire, but would build lines of exotic plants through our decadent forests and these plants would eventually serve as sources for the spread of the constituent species.

Ficus macrophylla, Moreton Bay fig. Growing on koa tree-stump from seed scattered by airplane in 1923.



Araucaria excelsa Norfolk Island pine, 8 years old, at Wahiawa. Planted May 1921; photographed August, 1929

Melaleuca leucadendron, Paper bark tree 8 years old Planted in 1921 photographed in 1929

Paper bark tree, 2 years old From seed spotting

Paper bark tree, 2 years old Planted on waste land

Some results from Seed Spotting in 1927.
Photographs taken in 1929.

Rose Apple

Mango

Melaleuca leucadendron, Paper-bark tree.

Ficus nota, Wild fig.

Terminalia myriocarpa, "Jhalna," 8 years old. At Oahu Sugar Company.

Trema orientalis, "Charcoal tree," 4 years old.

Forest reserve planting at Waipio John Ii Estate

Casuarina equisetifolia, Ironwood Planted along waterways to keep down grass growth Kahuku Plantation Company

Extensive Waste Land Planting
by Oahu Sugar Company

Waste land Plantings
by Honolulu Plantation Company
Planted in 1927 Photographed in 1929

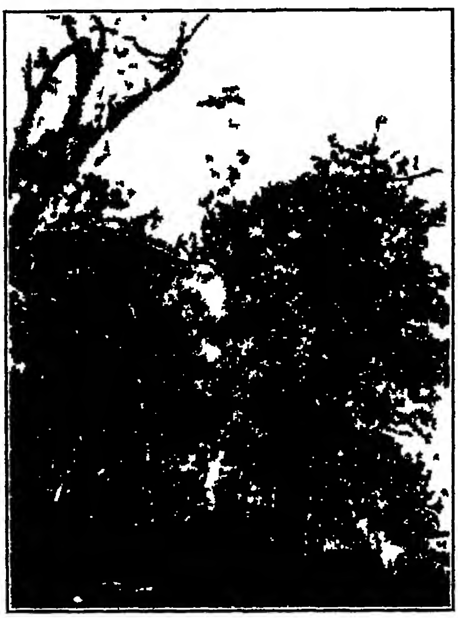
Albizzia moluccana 2 years old

Acacia arabica

Albizzia moluccana 3 years old

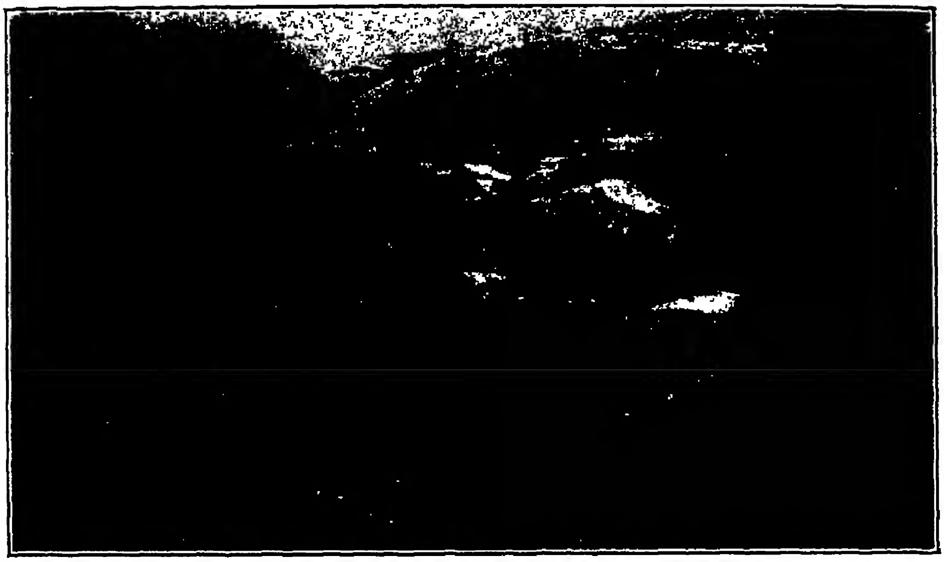
Site of Poamoho arboretum as seen from the air

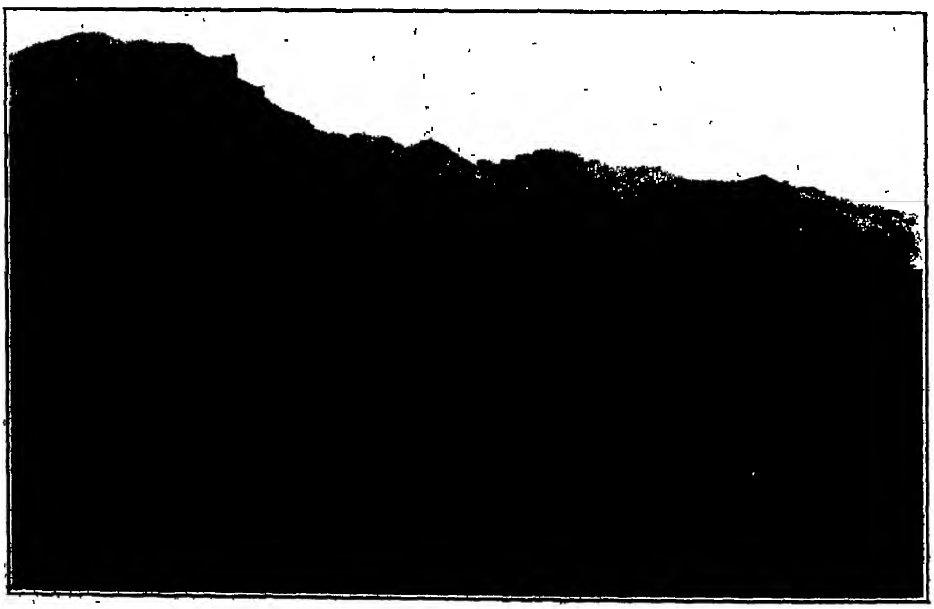
Burning *Uluhe*, staghorn fern, in clearing for Poamoho arboretum



Albizzia moluccana 2 years old. From seed spotting

Types of Erosion we are Trying to Control.



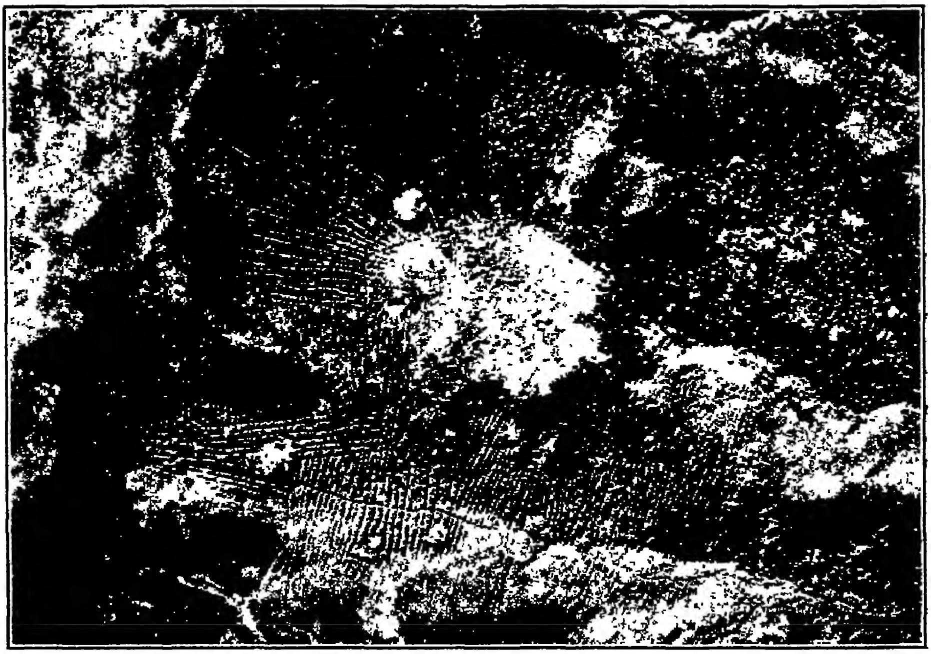


Firebreak, 50 feet wide. Built by U. S. Army, Schofield Barracks.

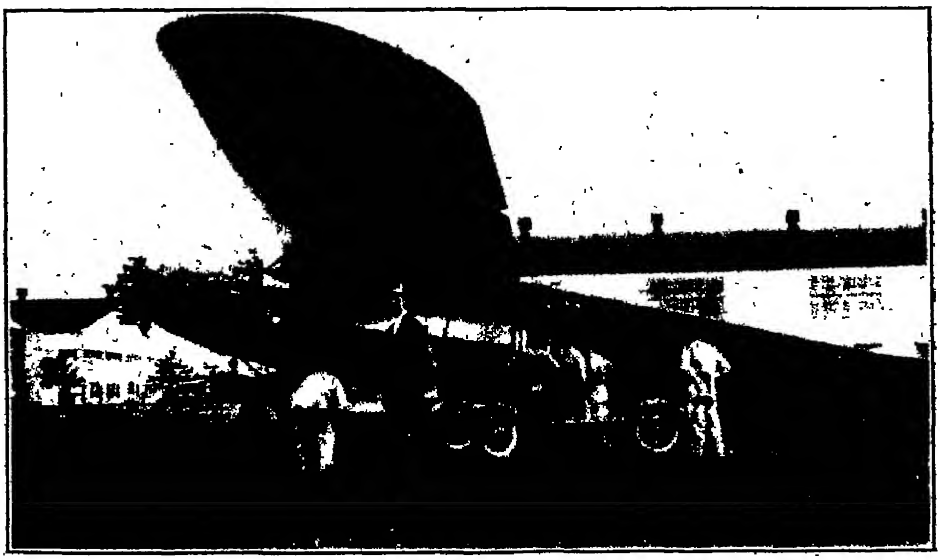
Ornamental planting, using *Ficus rubiginosa* trimmed to shape. At Ewa Plantation Company.

Cedrela australis, 3 years old. At Waialua Agricultural Company.

Gate post, 25 years old. *Eucalyptus globulus*. At Maunawili Ranch.



View from air of waste-land planting. Waialua Agricultural Company. Photographed in 1928 by Eleventh Photo Section. U. S. Army Air Service.



U. S. Army Fokker airplane loading bags of tree seed.

Some Observations on the Wilting Coefficient of a Selected Waipio Soil

By H. A. Wadsworth* and U. K. Das†

The purpose of the investigation reported in the present paper was threefold:

(1) A preliminary study of the physical properties of the selected soil and the determination of its critical soil moisture constants. Proposed work on the water cost of sugar cane and of sugar under Hawaiian conditions required a more complete knowledge of the properties of the selected soil type than was available.

(2) To determine whether the highly colloidal soil under investigation possessed a more or less definite wilting coefficient as defined by Briggs and Shantz(4).

(3) To determine the mathematical relation between this wilting coefficient, if one is determined, and other measurable soil moisture constants, such as the moisture equivalent and the maximum water-holding capacity.

Briggs and Shantz(4) define the wilting coefficient as the moisture content of the soil (expressed as a percentage of the dry weight), at the time when the leaves of a plant growing in that soil first undergo a permanent reduction in their moisture content as a result of deficiency of soil-moisture supply. By permanent reduction is meant a condition from which the leaves cannot recover in an approximately saturated atmosphere without the addition of water to the soil. These investigators working with more than a score of soils and hundreds of species, report results which lead them to conclude that the wilting coefficient is a definite soil moisture constant. Slight differences in residual moisture which occur when different species are used for indicator plants are attributed to a more perfect root distribution with one species as compared with another and not to the ability of one variety to exert a greater attractive force upon the soil moisture than another.

A mathematical analysis of the results obtained from these experiments in comparison with other commonly used soil moisture constants suggested the following equations:

$$(1)\quad \text{Wilting coefficient} = \frac{\text{Moisture equivalent of Briggs and McLane(3)}}{1.84\ (1 \pm 0.007)}$$

$$(2)\quad \text{Wilting coefficient} = \frac{\text{Hygroscopic coefficient of Hilgard}}{0.68\ (1 \pm 0.012)}$$

Although the second of these formulas has been discredited by Puri(7) and others who object to the use of the hygroscopic coefficient as a critical moisture constant, the first remains as a useful tool in irrigation research.

Although Veihmeyer and Hendrickson(10) have verified the findings of Briggs and Shantz with respect to the insignificance of botanical differences in indicator plants used for the determination of the wilting coefficient, these in-

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vestigators report a greater variation in the constant factor in the denominator than is indicated by Briggs and Shantz. In fact, a value as high as 2.27 is reported for Stockton clay which, according to the U. S. Bureau of Soils, carries about 60 per cent colloidal clay. There is no known relation between these empirical constants and the type of soil used. Apparently there is no method of determining this ratio except by an actual trial with the use of plants.

Not all investigators will grant that the residual moisture in a soil at the time of true wilt depends entirely upon the soil type. Caldwell(5) and Shive and Livingston(8) seem to find that the wilting coefficient is dependent upon the intensity of the evaporating power of the environment for the period during which permanent wilting is attained

Most research workers in irrigation believe the results of Briggs and Shantz to be sound in principle at least.

Since the wilting coefficient represents the lower limit of readily available soil-moisture its application to irrigation studies is evident.

Physical Properties of the Soil Used

As has been indicated the soil used for the observations reported in this paper was secured from the experimental field of the H. S. P. A. substation at Waipio. The site selected was typical of a rather large area. The soil was fairly uniform to a depth of three feet and well drained. It was doubtlessly alluvial in origin.

A small area, close to the selected site, was levelled, enclosed in a low dyke and flooded to a depth of five and one-half inches for the determination of the maximum water-holding capacity of the soil. An average of eight samples taken twenty-four hours after irrigation indicated a maximum water-holding capacity of 34.3 per cent. The variations between samples was so great, however, that the probable error in these results is high.

The moisture equivalents* determined from the same samples gave a value of 32.1 ± 0.2.

The colloidal content and fractional distribution of particles below arbitrary size limits was determined by means of a special hydrometer designed for this purpose by Bouyoucos(2). Volume weight determinations were made in the field by the use of viscous fluids as described by Beckett(1). A summary of these results, together with those already reported, is given in the following table:

PHYSICAL PROPERTIES OF WAIPIO SOIL USED IN WILTING COEFFICIENT DETERMINATION

Maximum water-holding capacity (average of 8 samples)	34.3 per cent
Moisture equivalent (10 samples)	32.1 ± 0.2 per cent
Real specific gravity (5 samples)	2.60

* The authors are indebted to K. B. Tester, of McBryde Sugar Company, Ltd., for the determination of the moisture equivalent, the colloidal content and the distribution of soil separates as shown.

Colloidal content (average of 10 samples)	51.2 per cent
Approximate per cent of particles below (average of 10 samples)	
.025 mm.	68.0 per cent
.010 mm.	54.0 per cent
.006 mm.	44.0 per cent
Volume weight (average of 6 samples)	1.1

Soil for use in the pots was secured from a shallow trench close to the flooded area. This material was mechanically screened in Honolulu and turned six times on a concrete floor to insure thorough mixing.

The pots used were gallon cans such as are used in canning plants. They were coated inside with a mixture of cement and sand and brought to a uniform weight of one pound three ounces by means of iron scrap placed in the bottom. Each can was filled to contain 6.65 pounds of oven dry soil, the moisture content of the mixed soil being determined by samples taken during the filling.

Thirty-nine cans were used. These were divided into four series. Three buff bean (*Tethonia speciosa*) seedlings were transplanted into each of twelve cans; three sunflower seedlings (*Helianthus annuus*) were transplanted to each of twelve cans in the second series, while each of the twelve cans of the third series was planted with a single eye, one joint, seed piece of sugar cane (H 109). Each joint weighed two ounces. Each of the remaining cans was planted with one bean, one sunflower and one cane eye.

The cans were carefully sealed to prevent loss of water by evaporation from the exposed soil surface. This was done by fitting a lead-foil disk into the can and waxing it to the sides. Small holes were provided for the stems of the seedlings. A general view of the equipment is shown in Fig. 1.

Since the tare weight of the can was known as well as the dry weight of the soil, the moisture content of any can could be determined by weighing the system. These weighings were made daily (Fig. 2).

The Determination of Wilt

As has been noted, true wilt is evident when a plant showing loss of turgor fails to revive when placed in a saturated atmosphere and a low temperature. If the plants regain turgidity, Briggs and Shantz assume that apparent wilt is due to a rate of transpiration in excess of the rate at which water is available from the soil. Such a condition might be occasioned by environmental factors making for a high transpiration rate, or a low conducting capacity in the plant tissue. Wilt of this sort is called temporary or incipient wilt. Such wilt may occur at any moisture content and can only be distinguished from permanent wilt by subjecting the plant to such an environment that the transpiration rate is greatly reduced. In the present experiment such an environment was provided in a high humidity chamber. This was a small, portable, cloth-walled closet placed in a tent which was constantly sprayed on the inside by fine streams of water. Dry and wet bulb

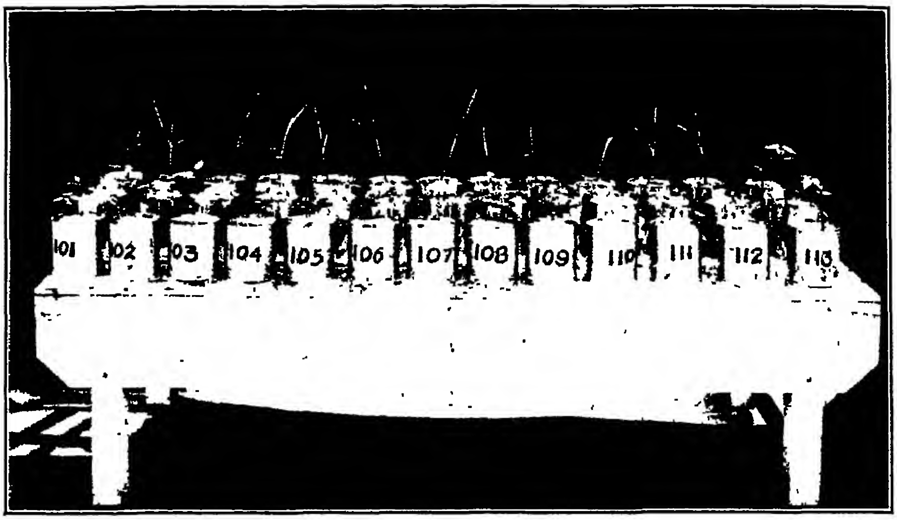


Fig. 1. A general view of the equipment.

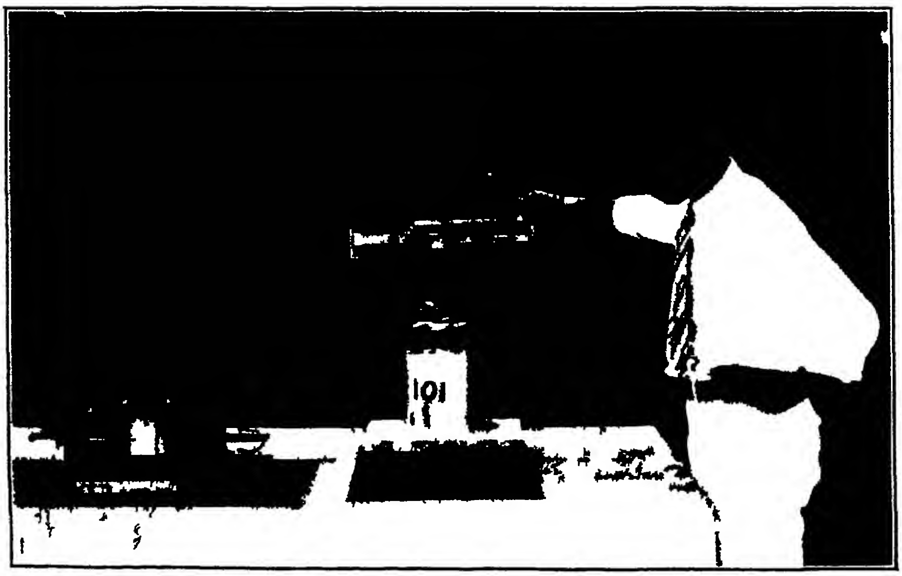


Fig 2

thermometers inside the chamber indicated a fairly constant temperature of 74° F. with a relative humidity of from 94 per cent to 96 per cent.

Plants showing signs of wilt were at once removed from the bench and placed in the high humidity chamber. If, after ten hours, signs of wilt persisted the wilt was called true wilt and the residual soil moisture content determined by careful weighing and computation. If complete turgidity was restored the plants were returned to the bench and the observations continued.

Recognition of Wilt

Perhaps the greatest source of error lay in correctly judging true wilt in accordance with the definition given above. As Briggs and Shantz(4) point out, transpiration continues long after this condition exists if environmental factors create a sufficient vapor pressure deficit about the transpiring surfaces. For this reason delay in removing a plant at the first sign of incipient wilt may result in error; if this is the only error involved the reported wilting coefficient is less than the real value.

Fig. 3. Simultaneous wilting of three species. The three species show characteristic signs of wilt.

The plants used showed signs of wilt in different ways. The sunflower showed a slight curling at the edges of the leaves, the leaves becoming slightly "leathery" to the touch. The beans turned slightly darker in color; the leaves changed from concave, as viewed from above, to convex; the angle between the petiole and stem became sharply acute. Cane leaves showed a distinct curling along the axis. Since new leaves unroll upon normal development it is at times difficult to determine whether observed curl is due to a maturing of the tissue of a new leaf or due to wilt. Fig. 3 shows can No. 113 at the wilting point. Characteristic wilt is observed in all species.

Results

Bean Series: Soils in this series were allowed to reach the wilting coefficient twice. This was accomplished by removing the lead-foil seal from each can as wilt was determined and irrigating to maximum water-holding capacity. The seal was then replaced and the observations continued. The cans were opened at the time of the second wilt and the residual soil moisture determined by oven drying as a check on the methods and observations at the time of filling. Inspection of the root distribution at this time indicated an adequate distribution of roots within the soil mass.

The methods described above gave the following mean values with the corresponding probable errors:

First wilting	23.3 ± 0.14%
Second wilting	23.5 ± 0.10%
Residual moisture by oven drying	23.7 ± 0.10%

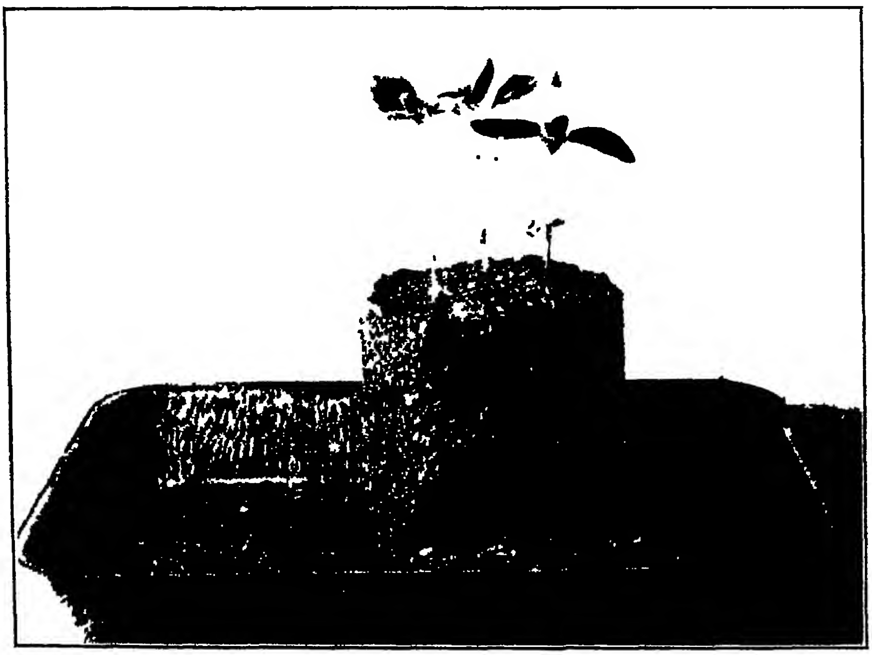
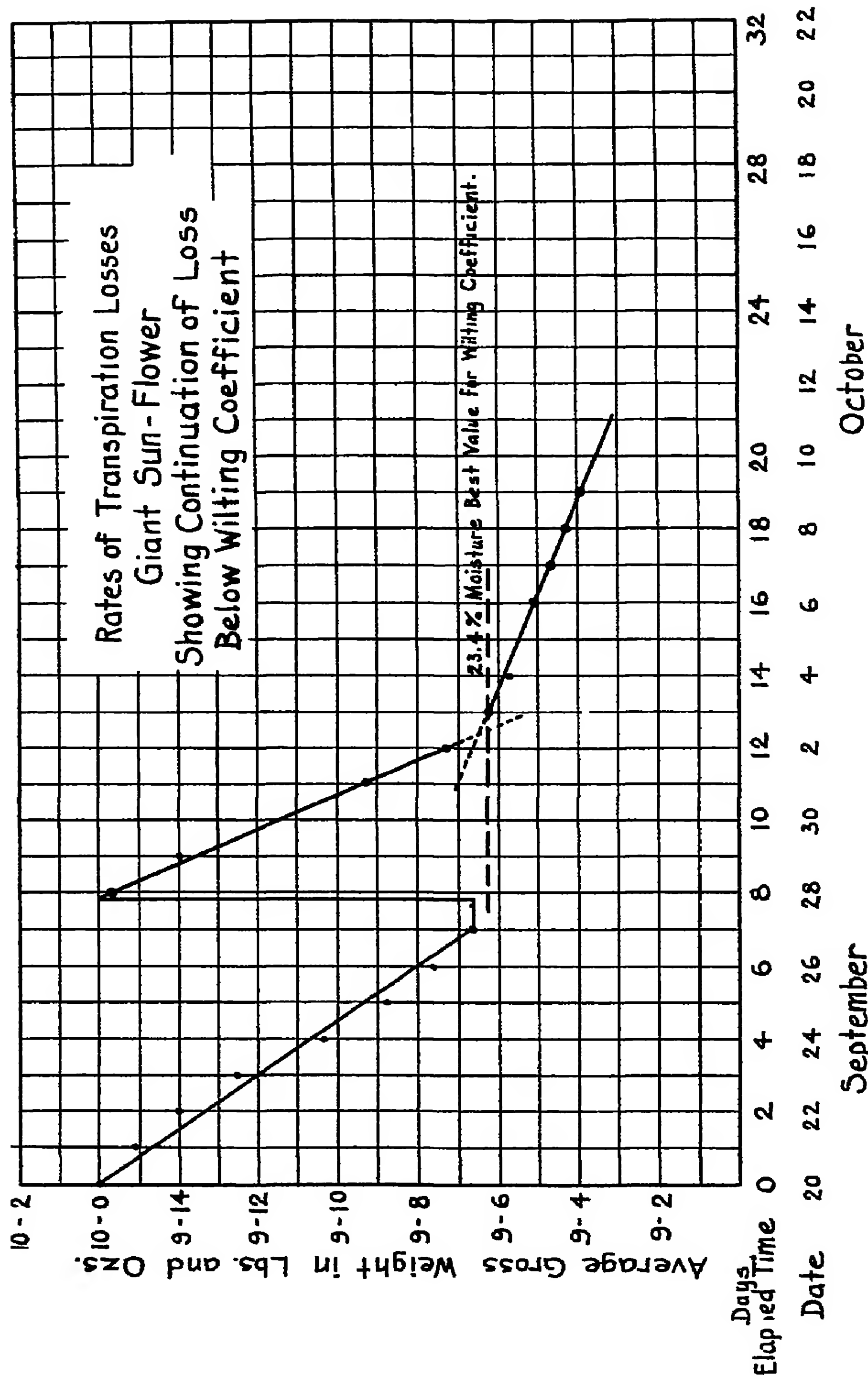


Fig. 4. Can No. 202 open for inspection.



Rates of Transpiration Losses
Giant Sun-Flower
Showing Continuation of Loss
Below Wilting Coefficient
23.4% Moisture Best Value for Wilting Coefficient.
Average Gross Weight in Lbs. and Ozs.
10 - 2
10 - 0
9 - 14
9 - 12
9 - 10
9 - 8
9 - 6
9 - 4
9 - 2
Days Elapsed Time
0 2 4 6 8 10 12 14 16 18 20 24 28 32
Date
20 22 24 26 28 30 2 4 6 8 10 12 14 16 18 20 22
September
October

Sunflower Series This series was allowed to wilt twice except for cans Nos. 202 and 205, which were opened at the time of the first wilt to determine the adequacy of the root spread and the uniformity of soil moisture depletion. Fig. 4 shows can No. 202 open for inspection.

Cans in this series were not destroyed for oven drying at the time of the second wilting, but were irrigated again and allowed to remain on the bench until death occurred; the weighings continued daily. The mean daily weight is plotted against time in Fig. 5. The change in rate of loss after the third wilting apparently indicates a change in the availability of soil moisture at a soil moisture content approximately equal to the wilting coefficient as determined by other means. From the uniform rate of loss between irrigation and wilting coefficient as is evidenced by the straight lines between September 20 and September 27, and between September 28 and October 2, one may conclude that water is equally available between these limits. In fact, Veihemeyer(9) concludes from similar curves and other evidence that "there appears to be no reason, either from physical considerations of the forces involved between the moisture and the soil particles or from physiological requirements of the plant, why optimum moisture conditions for growth should not vary from the maximum field capacity to about the wilting coefficient."

The results of the determination of the wilting coefficient by the use of the sunflower series are:

First wilting ...	22.8 ± 0.14
Second wilting	23.5 ± 0.16

Cane Series: Plants in this series showed physiological characteristics never before reported by investigators of the wilting coefficient. The logic upon which the method used with the bean and sunflower series is based assumes that there can be no absorption of water or water vapor by the leaves of a plant showing signs of incipient wilt, when that plant is placed in a saturated atmosphere. It is assumed that turgidity is restored by a movement of moisture from the soil, this rate of upward movement being great enough to exceed the reduced rate of transpiration in the high humidity chamber and to restore complete turgidity in the leaf tissue within something less than twelve hours. The present work seems to show that the wilted cane leaf is peculiar in that it possesses a decided capacity for absorption of water vapor or liquid water. A wilted cane cut at the ground surface and sealed at its cut end with wax regained full turgidity over night when suspended under a fine spray; a mature, discarded cane plant with wilting so complete that burning of the leaf tips had begun regained turgidity over night under a similar spray; plants in the cane series regained turgidity in the standard humidity house, although the soil moisture in the cane had dropped to 12.8 per cent because of transpiration through flaccid tissue as described under the discussion of the sunflower series. Although growth was handicapped or stopped entirely during this period it was impossible to note the time and consequently the residual soil moisture at the time normal growth ceased.

Additional evidence as to the water absorptive capacity of sugar cane leaves is furnished by the usual Hawaiian field practice of treating chloroitc plants with a

solution of iron sulphate, as reported by Verret(11). The cure is local initially. Dates and initials painted on chlorotic leaves appear in green upon a yellow background Although the physiology involved is not clearly understood the cures may involve the admission of the solutions through the leaves. A dry dusting of the leaves of chlorotic plants with powdered iron sulphate seems somewhat less effective than solutions, according to observations at the Experiment Station, H. S. P. A. Lee and McHargue(6), working with the Pahala blight of cane, report little or no effect with dry iron sulphate dust and only a slight response with powdered manganese salts. It has been suggested that such material is only available as it is dissolved in water of condensation.

Because of this difficulty the usual method for the determination of the wilting coefficient with cane as an indicator was necessarily abandoned. All cans in the cane series were irrigated to maximum field capacity, giving gross weights of 10 pounds 2 ounces. The cans were weighed daily at 1.00 p. m. The results of these weighing are shown graphically in Fig. 6. The significant change in rate of loss at 9 pounds 8.3 ounces may indicate a change in the availability of moisture at 23.4 per cent, which corresponds to this gross weight. The nearness with which this figure approximates the results of other more standard methods of determining the wilting coefficient for this same soil type adds weight to such an assumption. Another factor contributing to this change in rate of transpiration may be curling of the leaves with loss of turgidity and a consequent protection of the transpiring structures. In any event there seems to be a critical soil-moisture content with cane, as in other plants, below which plan's function differently than when soil-moisture is more abundant. And this critical soil moisture constant for cane is numerically close to the wilting coefficient for other plants. Apparently, if the term "wilting coefficient" is to be applied to soils of interest to sugar cane growers, the term must be redefined or used with reservation.

It must be borne in mind that other factors than unavailable soil moisture may have caused the results shown in Fig. 6. An abrupt change of environmental factors on October 25, which would reduce the evaporating power of the air and consequently lower the transpiration rate would cause a similar break. A recording thermo-hygrometer in constant operation showed no significant change in temperature or relative humidity at this point. In fact, the higher than normal temperature and lower humidity on October 27 would suggest a greater loss than usual on this day. No means were available for measuring sun intensities during this period.

These facts together with the distinct curling of leaves a few hours after sunrise after October 26, a slight retardation in rate of growth after this date and the close coincidence of the residual moisture content at this point with the standard wilting coefficient as determined with other crops, indicate that this change of rate of loss is of physiological significance.*

* Work subsequent to that reported in the main body of the paper indicates that the residual soil-moisture content at the time cane ceases growth is the moisture content which would result in wilt with other species.

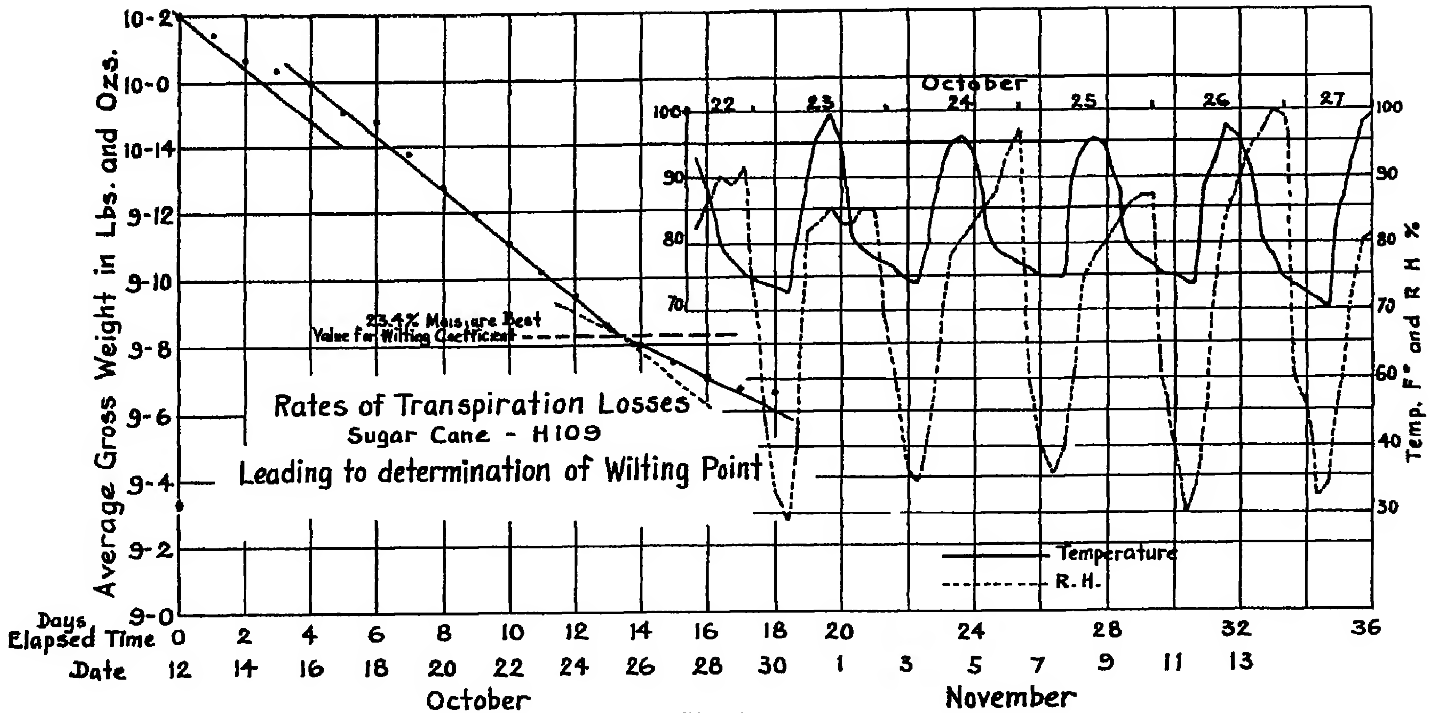

Rates of Transpiration Losses
Sugar Cane - H109
Leading to determination of Wilting Point
Average Gross Weight in Lbs. and Ozs.
10-2
10-0
10-14
9-12
9-10
9-8
9-6
9-4
9-2
9-0
Days Elapsed Time
0 2 4 6 8 10 12 14 16 18 20 24 28 32 36
Date
12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13
October
November
23.4% Mois. are Best Value for Wilting Coefficient
October
22 23 24 25 26 27
100 90 80 70
Temp. F° and R H %
100 90 80 70 60 40 30
Temperature
R. H.

Fig. 6.

Summary

(1) Fifty-eight observations of the wilting coefficient of Waipio soil using beans and sunflowers as indicator plants give a mean value of 23.4 ± 0.1.

(2) There seems to be no significant difference* between the results obtained with beans and with sunflowers, or between the results with beans by computation of the percentage of residual moisture and its actual determination by oven drying, or between successive wiltings with either species.

(3) Sugar cane leaves seemed to exhibit the unusual physiological property of being able to restore lost turgidity over night, regardless of the moisture content in the soil supporting the plant. However, a change in the transpiration rate under practically constant environmental factors was noted when the soil moisture had been depleted to the moisture content identified as the wilting coefficient with other plants. This period of the retarded transpiration was characterized by a retardation in rate of growth and by a consistent curling of the leaves.

(4) The present study of one soil only, indicates that a constant of 1.37 should be used in the denominator of the Briggs and Shantz equation for the empirical determination of the wilting coefficient, thus (for the selected Waipio soil):

$$\text{Wilting coefficient} = \frac{\text{Moisture equivalent}}{1.37}$$

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*This difference is, in all cases, less than five times the square root of the sum of the squares of the probable errors of the quantities under consideration.

The Relation of Molasses to the Micro-Biological Activity in Soil

By A. Floyd Heck

Too often the soil has been considered from the purely chemical or mineralogical standpoint as an inert mass of primary and secondary minerals, instead of the active living thing that it really is. In a recent paper, Moir (2) has recognized the biological phase of soil activity and called attention to the need for its study in Hawaiian soils. Fertile soils are not dead but are very much alive and teeming with countless millions of many kinds of organisms. Based on numbers, bacteria will take the lead in the soil population but in quantity of micro-organic material present in the soil, the fungi will usually stand first. The amount of micro-organic material in the form of yeast cells and actinomycetes will probably be intermediate, depending on the kind and amount of energy material present for their growth.

The activities of soil micro-organisms depend very much upon environmental conditions such as temperature, aeration and moisture, but of greatest importance is the amount and kind of organic material present upon which the organisms may draw for their energy supply. Proteinaceous materials are largely decomposed by bacteria, while the simpler carbohydrates, such as sugars and starches are used by both bacteria and yeasts. The destruction of the more woody tissue, consisting largely of cellulose or cellulose-like substances, is accomplished for the most part by the soil fungi and particularly certain species of the higher groups. Under any set of conditions there is always an equilibrium established between the activities of these organisms and their environmental conditions. Favorable temperature, aeration and moisture conditions cause more rapid biological activity which reduces the energy supply and a new balance is established. Under the favorable climatic conditions of Hawaii the available organic energy material has been reduced to a point where the biological activity or the "life factor" of the soil has reached a very low stage, lower, in fact, than most of the poorer soils of the mainland when placed under similar conditions.

This "life factor" or biological balance is very important in its relation to the plant nutrients and regulates to a large extent their availability to the growing plant. This is more especially true of nitrogen than either of the other elements because micro-organic material contains from 2 to 10 per cent of nitrogen. The extent of this relation with phosphorus and potassium is not known, but it is no doubt greater than many of us have thought. Although the total nitrogen may be high, in most normal soils with a normal biological balance, there is seldom more than a small amount of nitrate or ammonia nitrogen. This condition is nature's wise provision which not only protects the soil from heavy losses of nitrogen as nitrate, but also regulates the supply to the growing plant in the amounts best suited to its nutritional needs. A plant is much the same as an animal, not only requiring a balanced nutrition but also the proper amount at the proper time. In

the role of this balancing factor soil micro-organisms perform one of their greatest functions.

When molasses is placed in the soil the energy balance is disturbed and a very rapid biological action takes place because of the added energy material for the soil micro-organisms In case of the molasses, this added energy material is sugar and other easily decomposed carbonaceous substances. The plate counts of yeasts and bacteria for a 10-ton application of molasses is given in Table I, and shows a very rapid increase in the soil population.

TABLE 1

Plate Counts of Yeasts and Bacteria in Soil After the Addition of Molasses at the Rate of 10 Tons per Acre

	Millions per Gram of Soil		
	12 hours	24 hours	48 hours
Yeast—control	22.5	25.0	10.5
10 tons molasses	25.5	380.0	145.0
Bacteria—control	107.5	183.0	151.5
10 tons molasses	169.5	2020.0	30[illegible]5.0

If sucrose and glucose equivalent to that in 10 tons of molasses is added to the soil a similar increase in the number of organisms takes place, except that in this case the increase is not so great. This shows that the non-saccharine carbonaceous substances also assist in the biological activity on the addition of molasses. Table II shows the increase when the sugars alone are added to the soil.

TABLE II

Plate Counts of Yeasts and Bacteria in Soil After the Addition of Sucrose and Glucose Equivalent to that in Molasses at the Rate of 10 Tons per Acre

	Millions per Gram of Soil		
	12 hours	24 hours	48 hours
Yeast—control	29.0	23.0	28.0
sugar	26.0	217.0	80.0
Bacteria—control	81.0	87.0	102.0
sugar	244.0	803.0	1620.0

These figures show a decided increase in the number of organisms between 12 and 48 hours. Although the number of bacteria present is much greater than the number of yeasts, when the size of these two organisms is considered, probably over 90 per cent of the micro-organic material produced is made up of yeast cells. These figures show the correctness of McGeorge's (1) suggestion that the rapid biological activity in the soil on the addition of molasses was due to the growth of yeasts. At the end of 48 hours about 85 per cent of the sugar applied in the molasses had been used up by the organisms, and the remaining 15 per cent was used within the next few days.

Carbon Evolution

With the destruction of the sugars and the growth of soil organisms comes a rapid rise in temperature and an evolution of carbon dioxide as a by-product. It has been found that the evolution of carbon dioxide from a soil is one of the best measures of biological activity. In the case of the molasses the bulk of the carbon dioxide is evolved during the first 48 hours, and correlates both with the number of organisms and with the temperature rise. Fig. 1 shows graphically the evolution of carbon dioxide and the temperature rise for the first 7 days from the application of molasses at the rate of 10 tons per acre.

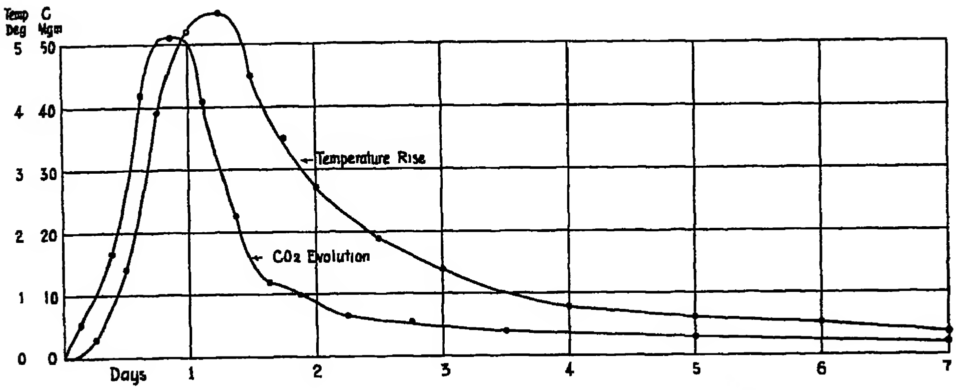

Fig. 1. Showing rise in temperature and the rate of evolution of carbon dioxide for a period of seven days after the addition of molasses at the rate of ten tons per acre 2,000,000 pounds of soil.

The carbon from the sugars is lost more rapidly than that from the non-saccharine substances. At the end of 10 days about 56 per cent of the carbon in the sugar and 35 per cent of that in the non-saccharine substances was evolved as carbon dioxide. The amount of carbon evolved as carbon dioxide during the first 10 days is governed somewhat by the amount of available nitrogen present for the organisms. With a small amount of nitrate nitrogen present 49 per cent of the total carbon in the molasses was lost during the first ten days, but if an abundance of nitrogen was present 59 per cent was evolved as carbon dioxide. This shows that nitrogen hastens somewhat the decomposition of the molasses by supplying that element to the growing organisms.

At the end of ten days all of the sugars and all traces of any pigment materials in the molasses have disappeared. If by this we may assume that the molasses has entirely decomposed and still 40 per cent of its carbon is retained in the soil, then it must have been assimilated by the soil organisms and built up into micro-organic tissue. If this is true, then at the end of ten days after the application of 10 tons of molasses to a soil there has been produced approximately 3 tons (dry basis) of living organic matter, perhaps 90 per cent of which is in the form of yeast cells. This form of organic matter is very unique and perhaps never occurs except under these peculiar conditions. In all of the writer's experience

yeasts have never been considered as a very large factor in soil fertility. When ordinary organic matter, such as green manures, are plowed down the decomposition is largely by bacteria and fungi and the organic matter left in the soil is largely inert or dead material. With the yeasts resulting from the use of molasses, the added organic material is living, high in nitrogen and very active and has the advantage over dead material that its availability will be slower and extend over a longer period of time. This is of especial value under the climatic conditions of Hawaii where decomposition goes on 12 months of the year, and dead organic material such as green manures goes out very rapidly.

The biological activity of the soil is greatly increased by the addition of molasses. Even after the sugars have all disappeared and perhaps none of the original organic substances added in the molasses are left, the soil is much more active biologically than the control soil. Between the tenth and the eighteenth day after its application from six to eight times the amount of carbon dioxide is evolved from the soil treated with 10 tons of molasses per acre than from the untreated soil.

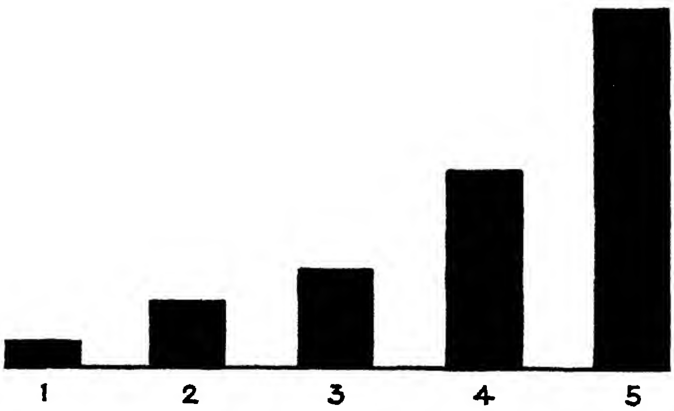

Fig. 2. The relative biological activity for the period between 14 and 18 days after a soil containing 328 p.p.m. of nitrate nitrogen is treated with varying amounts of molasses.
1. Control, no molasses.
2. 2½ tons molasses per acre 2,000,000 lbs. soil.
3. 5 tons molasses per acre 2,000,000 lbs. soil.
4. 10 tons molasses per acre 2,000,000 lbs. soil.
5. 20 tons molasses per acre 2,000,000 lbs. soil.

This is a very good indication of the relative biological activities of the two soils. In time this spread decreases and approaches the control but perhaps reaches it only after a very long period of time, if at all. This helps to account for the long continued beneficial effects that have been observed from the use of molasses. Fig 2 gives some idea of the relative biological activities of a soil containing 328 p.p.m. of nitrate nitrogen when treated with varying amounts of molasses.

Nitrogen Relations

Of even greater interest than the accumulation of organic matter as such, resulting from the application of molasses, or the increased biological action which

follows, is the relation which these activities bear to the nitrogen present in the soil as ammonia or nitrate. Almost immediately after the application of molasses to a soil there is a rapid disappearance of the nitrate or ammonia nitrogen present. This disappearance is almost directly proportional to the amounts of molasses used, and is equivalent to between 25 and 30 pounds of nitrogen for each ton of molasses. This nitrogen is not lost but used in the growth of the yeast cells and bacteria and built up into active living organic matter, from which it is liberated at a later period. Fig 3 shows the disappearance of the nitrate nitrogen from a soil containing 328 p.p.m. of nitrate nitrogen, when untreated, and when treated with amounts of molasses varying from 2½ to 20 tons per acre 2,000,000 pounds of soil.

There is a very close correlation between the drop in nitrates, the carbon evolution, the rise in temperature and the increase in number of micro-organisms, so that it seems rather safe to say that the whole process is biological and that the nitrogen is changed from inorganic or nitrate nitrogen to protein or organic nitrogen during the growth of the soil organisms. This is not denitrification in the true sense of the word but only a change from the inorganic to the organic form with no resultant loss of nitrogen and has no relation to the process of nitrification.

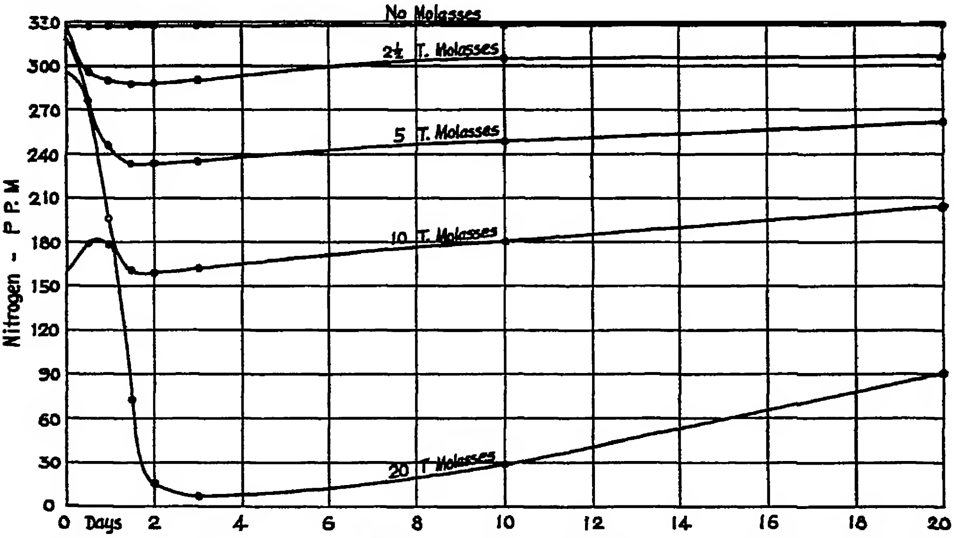

Fig. 3. Curves showing the disappearance and reappearance of nitrates after the application of molasses in varying amounts to a soil containing 328 p.p.m. of nitrate nitrogen.

For this nitrogen to become available to the growing plant it must again change to nitrate and this takes place in due course of time as the organisms die and decompose in the soil. The rate at which this takes place depends upon the amount of micro-organic material present, and this amount is governed by the amounts of molasses and nitrogen added in the beginning. If the amount of molasses is in excess of a ton for each 25 pounds of mineral nitrogen present, the nitrification rate will be slow, but if less than this amount it will be more rapid. It appears that for best results there must be something of a balance between the molasses and the mineral nitrogen. This may help to explain why the use of

molasses has sometimes given excellent results and at other times little or nothing. or delayed returns coming in the ratoon crop. There is also a physiological balance between the nitrogen as nitrate in the soil and the needs of the plant, and it appears that the combination that will furnish the nitrogen to the plant at about the rate which will best supply its assimilation needs, will give the best plant growth. In other words, a nitrification curve similar in form to the growth curve of the plant will perhaps give best results.

Conclusions

1. When molasses is applied to the soil under aerobic conditions, the sugar which it contains is decomposed and lost within three or four days and from 50 to 60 per cent of the total carbon in the molasses is lost in the first ten days.

2. There is a rapid rise in temperature corresponding to the evolution of carbon dioxide.

3. There is a rapid increase in the bacterial and yeast counts corresponding to the evolution of carbon dioxide and the rise in temperature.

4. The application of 10 tons of molasses per acre renders the soil thus treated from six to eight times as active biologically, after a period of two to three weeks, as the untreated soil.

5. Mineral nitrogen is utilized in the process of decomposition of molasses in the soil to the extent of about 25 to 30 pounds of nitrogen per ton of molasses decomposed, and a living, active micro-organic material formed in the soil which contains 4 to 6 per cent of nitrogen. Evidence indicates strongly that this organic material is largely made up of yeast cells.

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A Rapid Colorimetric Method for Phosphorus Determinations

By Ritchie R. Ward

The importance of phosphorus in studies of soil fertility, and of biological materials, has been recognized for many years. Methods for determining large amounts of phosphorus have long been known, but Taylor and Miller (1) were the first investigators to employ a colorimetric method for the estimation of small amounts.

This method depends on the blue color that is developed when the molybdate of phosphorus is reduced with phenyl hydrazine. A number of other reducing agents have been suggested (2), but stannous chloride, used by Denigès (3), and hydroquinone, used by Bell and Doisy (4) have come into most general use. The method of Bell and Doisy was subsequently modified by Briggs (5) and by Fiske and Subbarow (6), and has been used by Arrhenius in Java.

Parker and Fudge (7) studied these methods in relation to their merits for determining phosphorus in soils, and reached the conclusion that the method of Denigès is approximately five times as sensitive as that of Fiske and Subbarow.

Improvements on the Denigès method were recently made by Truog and Meyer (8), who made a detailed study of interfering substances, and worked out a procedure which eliminates such errors. They state that the improved method "appears to be one of the most satisfactory in the field of colorimetric methods and should find wide application in biology, agriculture and industry."

A large number of determinations of phosphorus are made in the Experiment Station chemical laboratory. The regular method is by precipitation as ammonium phosphomolybdate and subsequent titration, which is tedious and time consuming. A faster method of comparable accuracy was desirable; accordingly, a series of determinations was made by the colorimetric method of Truog and Meyer, and the results compared with those obtained by the regular volumetric procedure followed in this laboratory.

The reagents required for the colorimetric determination are given by Truog and Meyer as follows:

Ammonium molybdate—sulfuric acid solution: Dissolve 25 grams ammonium molybdate in 200 cc. of water heated to 60° C. and filter. Dilute 280 cc. of arsenic- and phosphorus-free concentrated sulfuric acid (about 36 N) to 800 cc. After both solutions have cooled, add the ammonium molybdate solution slowly, with shaking, to the sulfuric acid solution. After the combined solution has cooled to room temperature, dilute with water to exactly 1000 cc. This is a 10 N sulfuric acid solution containing 2.5 grams of ammonium molybdate per 1000 cc.

Stannous chloride solution: Dissolve 25 grams of $SnCl_2 . 2H_2O$ in 1000 cc. of dilute (10 per cent by volume) hydrochloric acid solution. Filter if necessary. Store in a bottle with a siphon or side opening near the bottom, arranged with a glass stopcock for delivering the solution in drops. The solution should be protected from the air by floating a layer of white mineral oil about 5 mm. thick over the surface.

Standard phosphate solution: Dissolve 0.2195 gram of recrystallized potassium dihydrogen phosphate and dilute to 1000 cc. This solution contains 50 parts per million of phosphorus and is too concentrated to use directly. A second stock solution is made by taking 50 cc. of the first stock solution and diluting to 500 cc. This second stock solution contains 5 p.p.m. and is used for making the standard solution for comparison.

A Kennicott-Sargent colorimeter was used for making the color comparisons. To make the standard solution for use in the colorimeter, take 25 cc. of stock solution containing 5 p.p.m. of phosphorus and dilute to 450 cc. with distilled water, add 20 cc. of ammonium molybdate-sulfuric acid solution and mix thoroughly by shaking in the volumetric flask. Add 30 drops of stannous chloride solution, and shake. Dilute to exactly 500 cc., shake, then wash out the colorimeter tube and plunger several times with the solution, finally filling the colorimeter tube. Insert plunger, and the colorimeter is ready for use.

Analytical procedure: In citric acid extracts precipitate the iron, aluminum, and phosphorus from solution with ammonia as usual, adding ferric chloride on which a blank has been determined, if necessary; wash thoroughly with hot water. A double precipitation is recommended. Wash the precipitate from the filter with a stream of water, taking care to include that part which sticks under the folds of the paper. Carefully dissolve with 1 to 1 sulfuric acid, using as little in excess as possible. From 1 to 5 cc. of 1 to 1 acid will be required, depending on the amount of precipitate. If the solution is more than faintly acid, bring the solution near neutrality with dilute caustic, stopping before the red color of phenolphthalein appears.

Wash the solution into a 500 cc. volumetric flask, make up to the mark, and pipette 5 cc. into a 250 cc. beaker or Erlenmeyer flask. Dilute to about 50 cc., add a piece of mossy cadmium to reduce ferric iron, and let stand several hours, or preferably over night.

Wash into a 100 cc. volumetric flask, add 4 cc. of ammonium molybdate-sulfuric acid solution, shake, add 6 drops of stannous chloride solution, make up to the mark and mix thoroughly.

The blue color appears immediately; if the color is less intense than that of the standard, pour the entire 100 cc. into the colorimeter comparison tube, and adjust the standard to match. If the solution contains more phosphorus than the standard, pour a correspondingly smaller amount into the graduated comparison tube and multiply the result by the proper factor.

If the solution contains more than twice the amount of phosphorus as the standard, it will be necessary to take an aliquot and repeat the procedure. Maintain the same amount of molybdate (4 cc.) and stannous chloride (6 drops) in 100 cc. final solution. It is not advisable to use a stronger standard, as the color developed will be too intense to allow accurate matching.

The volume of standard required to match the solution, multiplied by 0.0001145, gives the per cent citric acid soluble phosphoric acid, when the total iron-aluminum-phosphorus precipitate is made up to 500 cc. and a 5 cc. aliquot is taken.

Comparison with the standard should be made within 10 minutes after adding the stannous chloride. It has been found convenient to make up a separate standard

for each set of ten determinations; it is possible to make the ten comparisons within the allotted time.

Truog and Meyer outline the following general precautions:

> Reagents, filter paper, water, and glassware often contain appreciable amounts of phosphorus and arsenic. Blank tests should be made frequently in which all the reagents and glassware come into play; there should not be produced more than a very faint blue color, if everything is satisfactory. New glassware should be weathered for 24 hours in dichromate—sulfuric acid mixture. It is absolutely essential that each lot of new reagents be tested.

Munktell's No. 0 filter paper has been found to be practically free from phosphorus and arsenic.

Experimental results: A test was first made to determine whether the results obtained by the colorimetric method were reproducible. A series of duplicate determinations was run on a set of 35 soils; the results are presented in Table I. It will be seen from these figures that uniformly good checks can be obtained.

A comparison was next made between the results obtained by the colorimetric method and those obtained by the regular volumetric procedure. These figures are shown in Table II. In column A are shown the results using the regular method; in column B are shown the colorimetric results on the corresponding soil.

The straight line which best represents these points on a graph was calculated by the method of least squares. It is a line of slope 0.827, and if we let

x = per cent P_2O_5 as determined volumetrically,
y = per cent P_2O_5 as determined colorimetrically,

the equation of the curve is

$$\frac{y-0.0004}{.827}$$

In column C the value of y as given by the equation is presented, and the difference of this value from that actually observed appears in column D. In column E the corresponding percentage differences are shown.

TABLE I

Per Cent P_2O_5, Run 1	Per Cent P_2O_5, Run 2	Per Cent P_2O_5, Run 1	Per Cent P_2O_5, Run 2
.016	.016	.032	.032
.028	.027	.021	.021
.038	.037	.0096	.0092
.045	.046	.0073	.0082
.071	.079	.012	.011
.030	.029	.019	.017
.052	.056	.040	.039
.0087	.0082	.017	.017
.027	.026	.0069	.0064
.022	.022	.0055	.0050
.0082	.0092	.0046	.0050
.025	.025	.013	.013
.011	.011	0073	.0082
.0055	.0060	.0087	.0092
.0078	.0079	.0078	.0078
.043	.043	.0041	.0041
.012	.012	.0055	.0060
.027	.026		

These differences are then treated by the statistical method. It is found that the standard deviation of a single percentage difference is

$$\text{S. D.} = \sqrt{\frac{1233}{25-1}} = 7.2$$

and the corresponding probable error

$$\text{P. E.} = 0.6745 \times 7.2 = 4.8$$

This means that the probable error of calculating the per cent phosphoric acid from the equation is 4.8 per cent. To illustrate, if a colorimetric determination gave a value of 0.0035 per cent P_2O_5, the volumetric determination should give a value of 0.0038 ± 0.0002.

It is believed that this error is less than the respective errors of sampling the soil, extracting with citric acid, and finally, interpreting the results in terms of fertilizer practice.

TABLE II

A Per Cent P_2O_5 Volumetrically Obs. x	B Per Cent P_2O_5 Colorimetrically Obs. y	C Per Cent P_2O_5 Calc. From Equation Calc. y	D Difference Obs. y—Calc. y	E Per Cent Difference $\frac{\text{Obs. y} - \text{Calc. y}}{\text{Calc. y}}$	F Difference of E from Average E	G F^2
.0014	.0019	.0016	.0003	18.2	8.2	67.2
.0013	.0017	.0015	.0002	13.3	3.3	10.9
.0013	.0016	.0015	.0001	6.7	3.3	10.9
.0016	.0016	.0017	.0001	5.9	4.1	16.8
.0023	.0023	.0023	0	0	10.0	100.0
.0024	.0021	.0024	.0003	12.5	2.5	6.3
.0026	.0022	.0026	.0004	15.4	5.4	29.2
.0027	.0023	.0026	.0003	11.5	1.5	2.3
.0042	.0037	.0039	.0002	5.1	4.9	24.0
.0045	.0044	.0041	.0003	7.3	2.7	7.3
.0056	.0038	.0050	.0012	24.0	14.0	196.0
.0077	.0066	.0059	.0007	11.9	1.9	3.6
.0091	.0072	.0079	.0007	8.9	1.1	1.2
.0098	.0069	.0085	.0016	18.8	8.8	77.4
.0100	.0086	.0087	.0001	1.1	8.9	79.2
.0110	.0096	.0095	.0001	1.1	8.9	79.2
.0115	.0110	.0099	.0011	11.1	1.1	1.2
.0117	.0095	.0101	.0006	5.9	4.1	16.8
.0120	.0087	.0103	.0016	15.5	5.5	30.3
.0124	.0133	.0107	.0026	24.3	14.3	204.5
.0140	.0120	.0120	0	0	10.0	100.0
.0166	.0164	.0141	.0023	16.3	6.3	39.7
.0314	.0292	.0264	.0028	10.6	0.6	.4
.0478	.0395	.0399	.0004	1.0	9.0	81.0
.0574	.0464	.0479	.0015	3.1	6.9	47.6
				Σ = 249.5		Σ = 1211.0
				Avg. = 10.0		

A test was next made to determine the ability of different observers to match color intensity, as required in this method. Four different persons matched the solution and standard on the same sample. The volume of standard necessary to match the sample was found to be 76 cc. in one case, and 84, 87 and 92 cc. in the others. These readings differ widely, yet each observer was able to check his own reading within 1 or 2 per cent

In view of the fact that the personal equation enters so prominently into the matter of matching color intensity, it will be necessary for each analyst to determine his own curve, and advisable that he also determine the probable error of a single observation.

The above results appear to indicate that the colorimetric method may be used in determining phosphorus in soil extracts, without introducing errors larger than others already present.

The method is rapid and convenient, and is particularly useful when small amounts of phosphorus are to be determined.

Summary

(1) A rapid colorimetric method for determining phosphorus has been described.

(2) The results obtained have been shown to be reproducible.

(3) An equation for calculating the per cent of phosphorus as indicated by the standard method, from the results of the colorimetric method, has been developed.

(4) The influence of the personal equation on the method has been noted, and means for obviating the error so introduced have been presented.

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Boric Acid Absorption of Kjeldahl Nitrogen

By Arthur S. Ayres

The methods employed at this Station for the determination of nitrogen in fertilizers involve its reduction, from various forms, to ammonia. The ammonia, thus formed, is subsequently distilled through cooling coils into an accurately measured quantity of standard sulfuric acid solution. Back-titration with standard sodium hydroxide solution gives the amount of acid required to neutralize the ammonia distilled from the sample.

In 1913, Winkler (1) proposed the substitution of boric acid for sulfuric in the fixation of ammonia distilled over in the course of the Kjeldahl method for the determination of total nitrogen. By this substitution the necessity for back-titration is eliminated and the ammonia in the fixing solution is titrated directly with a standard acid. Scales and Harrison (2) investigated this method and found it to be equally as accurate as the standard sulphuric acid absorption. Spears (3) in 1921 conducted a series of sixty determinations on feed stuffs by both methods. The agreement obtained was very satisfactory.

The several advantages of boric acid over sulfuric acid in nitrogen determinations, as found by these investigators, has led us to consider its adoption in fertilizer analysis. A series of comparative tests of the two methods has been made and it is the purpose of this paper to present and briefly discuss the results.

In order to obtain a fair comparison of the two methods laboratory samples of fertilizers, taken largely in the order received, were analyzed as usual and checked in duplicate against the newer procedure. These samples contained nitrogen in widely varying percentages in one or more of the following forms: ammonia nitrogen, nitrate nitrogen and organic nitrogen. Routine separations, reductions, digestions, etc., were all made by official (A. O. A. C.) methods. Distillations were carried out in accordance with the regular laboratory procedure. In the case of the samples run by the sulfuric acid method the distillate was received into a sufficient excess of 0.2 N sulfuric acid to effect complete neutralization, using methyl red indicator. Where boric acid was used the distillate was received, at room temperature, into 50 cc. 4 per cent boric acid solution. Spears (3) found that 0.095 gram of nitrogen, as ammonia, could be recovered with accuracy from the distillate when this quantity of boric acid was used. This result was obtained without the use of glycerin which Adler (4) recommends. The ammonia was led as deeply as possible into the fixing solution during the first fifteen minutes of distillation, after which the condenser tube was raised so that the subsequent distillate would serve to rinse the tip. Blanks were run using all reagents. The standard acid employed as a neutralizing agent in the sulfuric acid method and for the direct titration in the boric acid method, was 0.2 N sulfuric acid.

Various indicators were tested in conjunction with the new reagent. Congo red was found to be the most satisfactory, although choice of indicator is somewhat

a matter of personal taste. Spears (3) recommends the use of bromophenol blue in this titration, using artificial light.

The indicator employed in this laboratory for the determination of nitrogen by the sulfuric acid method, is methyl red In the determination of ammonia nitrogen, Congo red has a decided advantage over this indicator The base used in the ammonia-nitrogen-determination is magnesium oxide, which contains magnesium carbonate as an impurity The carbon dioxide carried over during the distillation interferes with the proper action of methyl red, as an indicator, and hence must be removed prior to titration. The use of Congo red renders this step unnecessary Where boric acid is used as the fixing agent no attempt should be made to heat the distillate before titrating.

The results obtained by the two methods (see Table) show very close agreement in practically all cases. Other comparative tests by Van Brocklin, Shepardson and the writer, show equally close agreement. The average of all values shown in the table indicates that there is no systematic error involved. The averages of the deviations from the mean, 0.013 for the sulfuric acid method and 0.014 for the boric acid method, show no significant difference. The probable error, calculated from the data, is 0.0092 for the former method and 0.0100 for the latter, which is identical for practical purposes. The results appear to be equally satisfactory for each of the three forms in which nitrogen was determined, namely, ammonia nitrogen, nitrate nitrogen and organic nitrogen.

TABLE OF RESULTS

Sample	Per Cent Nitrogen by H_2SO_4 Absorption	Average	Per Cent Nitrogen by H_3BO_3 Absorption	Average
1	7.06		7.01	
	7.00	7.030	7.07	7.040
2	10.26		10.20	
	10.22		10.17	
	10.26	10.247	....	10.185
3	2.91			
	2.89			
	2.90	2.900	....	2.905
4	2.27		2.29	
	2.24	2.255	2.26	2.275
5	11.66		11.62	
	11.54		11.57	
	11.64	11.613	...	11.595
6	8.66		8.66	
	8.66	8.660	8.66	8.660
7	4.34		4.28	
	4.30	4.320	4.24	4.260
8	5.46		5.56	
	5.50	5.480	5.46	5.510

9	0.74		0.71	
	0.74		0.70	
	. . .	0.740	0.69	0.700
10	0.51		0.49	
	0.50		0.49	
		0.505	0.50	0.493
11	0.53		0.56	
	0.54	0.535	0.54	0.550
12	0.76		0.74	
	0.76	0.760	0.74	0.740
13	0.53		0.51	
	0.52	0.525	0.51	0.510
Average		4.27		4.26

The chief advantages of the new method over the old one are:

(1) Employment of one standard solution instead of two. This saves time and eliminates one possible source of error.

(2) But one accurate measurement is required instead of two. Time is again saved and the possibility of slight errors in reading the burette eliminated. Since the absolute amount of boric acid in the receiving flask need not be accurately measured, an unskilled assistant may do this part of the work, where a large number of nitrogen determinations are to be made. Scales and Harrison (2) found that this rough measurement of the acid saves from one-fourth to one-third of the time required to obtain equally accurate results by the old methods.

(3) The strength of the standard acid, and weights of samples taken can be so adjusted that the percentage of nitrogen can be read directly from the burette, or else obtained by the simplest mental arithmetic.

From a consideration of the advantages of the new method over the old and from the foregoing analysis of data, it is felt that the substitution of boric acid for sulfuric acid, as a fixing agent in the determination of nitrogen in fertilizers, is well justified.

Summary

1. The methods of nitrogen determination, as heretofore employed at this Station, involve the distillation of ammonia into an accurately measured quantity of standard sulfuric acid. The excess acid is then back-titrated with standard sodium hydroxide solution and the percentage of nitrogen in the sample calculated from the difference thus obtained.

2. The boric acid method of nitrogen determination, in which boric acid solution is substituted for sulfuric acid as the fixing agent, permits the direct titration of the ammonia in the distillate with standard acid.

3. Comparative tests on nitrogen in fertilizers have been determined by both methods in this laboratory. The agreement between the two sets of results thus obtained is very satisfactory.

4. It was found that the boric acid absorption is a time-saving expedient which may be employed without any sacrifice of accuracy.

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Forestry in Formosa

By J. P. Martin

While en route to Java to attend the Third Congress of the International Society of Sugar Cane Technologists, 1929, the delegates from Hawaii had the opportunity, through the courtesy of the government of Formosa, to observe some of the various Formosan industries.

Among the outstanding industries of Formosa is lumbering, and the forests are under the protection of the government. A trip was made to the forest of Arisan, which is one of the three principal forests The illustrations accompanying this article were taken while visiting the Arisan forest. In the higher elevations strange people, known as head-hunters, still inhabit the primeval forests. The savage proclivities of these primitive people are now kept under control and only an occasional uprising occurs.

The government of Formosa published, in 1926, a book entitled: *Progressive Formosa*. The following paragraphs, dealing with forestry in Formosa, are taken *verbatim* from this book:

Well-nigh one half of the surface of the island being covered with high mountains rising to a height of 6 9,000 ft. to 12 13,000 ft. above sea-level, there exists a large area of magnificent primeval forest.

The forests bordering on the plain had, under the Chinese regime, been to a great extent denuded of trees, owing partly to reclamation for agricultural purposes, and partly to fires and indiscriminate felling for timber and fuel, without any attempt at re-afforestation. The re-afforestation work was taken in hand after the advent of the Japanese, but has not yet made any notable progress Accordingly the unexploited primeval forests are now only to be found in the rugged high mountains far beyond the access of civilized settlers. The forests of Taiwan, owing to their geographical position, geological qualities, and climatic conditions, comprise an amazingly large variety of trees belonging to the tropical, sub-tropical, temperate and even the semi-artic zones. It is no wonder that the Portuguese navigators looking up at the verdant mountains from the high exclaimed: "Isle of Beauty!"

Among many large forests so far discovered, the most renowned are the Arisan, Hassenzan and Dakusui-kei forests, where exploitation is being actively carried on under the Government Forestry Bureau. In 1923, the volume of timber disposed of by the Government amounted to over 298,990 koku,* representing 3,559,000 yen† in value. Of the three great forests, the Arisan forest is the most important, standing foremost in respect of extent, wealth and beauty, and is fast becoming known to Japanese and Westerners as well. Arisan is the name given to a range of mountains stretching westward from Mt. Niitaka, and is situated about forty miles east of Kagi. The forest lies at an altitude ranging from 2,800 ft. to 8,700 ft. above sea-level, covering an area of 11,000 chobu (27,000 acres). The timber obtainable from the forest is estimated at 22,000,000 board feet. As for the distribution of the predominant trees, benihi (*Chamaecyparis formosensis*) grows mingled with other trees at an altitude of 6,000 feet above sea level, and from 7,000 feet upwards are found in turn, woods all composed of benihi and hinoki (*Chamaecyparis obtusa*), while tsuge (*tsuge formosa*) and himekomatsu (*pinus parviflora*) are found min-

* Koku = 9.8274 cubic feet.
† Yen = 50¢.

gled together at 8,000 ft. These innumerable trees form the magnificent primeval forests that have remained sacred and untouched from time immemorial.

The exploitation of the Arisan forests was started as a private undertaking by Fujita and Co., but was transferred to the Government through purchase in 1910. A railway more than 54 miles in length has been constructed for the transport of timber from the forests. The railway section from Kagi to Takezaki is opened to general traffic, but the line beyond Takezaki is very steep and is not open for public use.

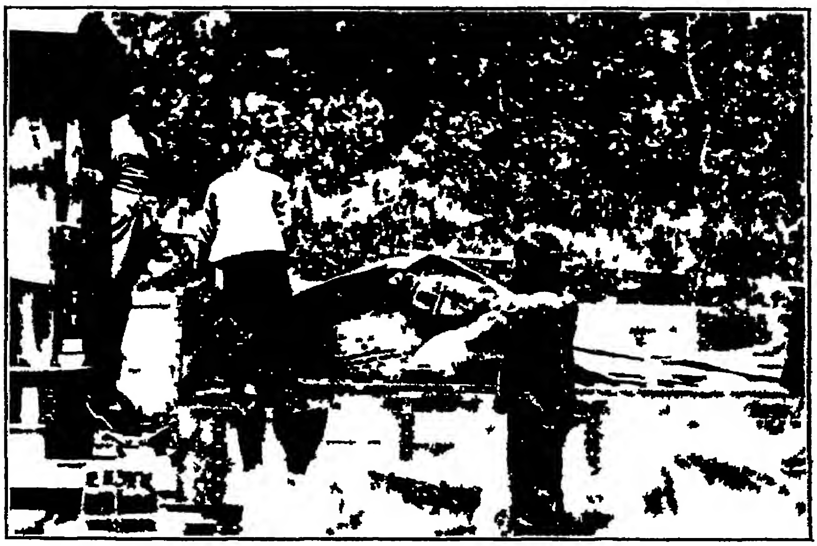
Special permission will however be given to visitors to Mt. Arisan to avail themselves of the line. The forest railway steams up crawling along rugged mountains and sharp cliffs in a spiral fashion and reaches the high elevation of 8,000 feet. The train in its journey passes through more than 73 tunnels as well as innumerable cuttings. The grand kaleidoscopic views and exciting experiences one can enjoy while ascending lofty mountains and traversing deep valleys are simply wonderful and quite beyond description.

By means of aerial cables the timber felled is conveyed and gathered at points accessible to railway stations and then transported down to the saw mills and Kagi, a distance of forty miles. The volume of timber obtained during 1923 amounted to 190,332 koku, corresponding to the value of 2,447,542 yen.

The lumbering business figures show that the Arisan forests alone are capable of yielding more than half of the whole production of the island and this vouches for a further development of the lumber industry in the same forests.

These primeval forests contain large numbers of old trees which have passed beyond their mature stage. The Government therefore has formed the plan of renovating the Arisan forests by felling aged trees and re-afforesting them afterwards. The Government is also carrying out afforestation schemes in various districts and is giving encouragement to private parties to engage in the same useful work. During 1923 the extent of newly planted land afforested both by the government and by private parties amounted to approximately 121,777 chobu.

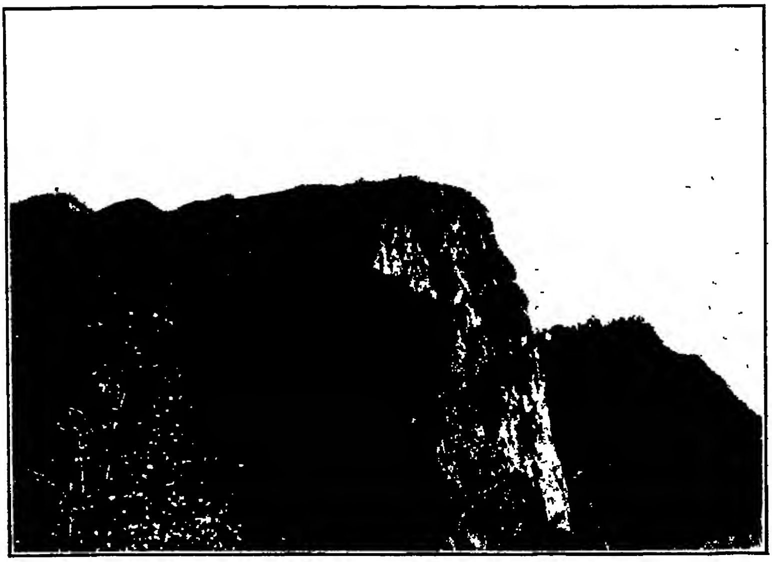
En route to the summit of Mt Arisan



Freight being transported to the lumber camps

Reforestation of slopes of Mt Arisan as viewed from the train

Village built entirely of bamboo, on the way to Mt Arisan



Rugged peaks.

Side-hill forests, Mt. Arisan.

Mountain scenery.

Heavy forests; elevation 8000 feet.

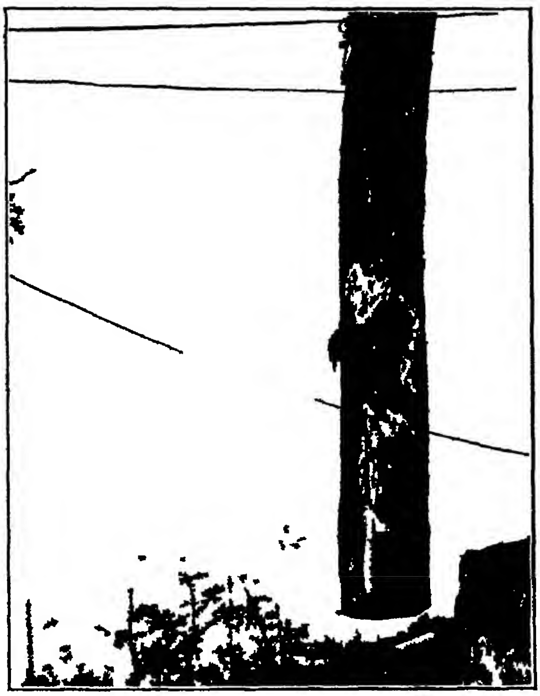
Newly planted forests; elevation 8000 feet.

A lumberman who had just felled a large tree.

A tree climber

Some of the delegates at a logging camp, Mt Arisan

A donkey engine for snaking logs to the railroad station



A large log being transported from the forest to the railroad station by aerial cables

Railroad passing through a forest that has been logged

Peaceful head hunters

"Close up" of the women head hunters

"Close up" of the men head hunters

The Decomposition of Carbohydrates in Water-Logged Soils, and the By-Products Remaining in the Soil

The investigations conducted by V Subrahmanyan are interesting to those planters who are retaining considerable amounts of cane trash in the fields and to all who are using, or are considering the use of, molasses as a soil amendment The work, done at Rothamsted Experimental Station and reported in *The Journal of Agricultural Science*, Vol XIX, October, 1929, is herein briefly reviewed.

Potassium nitrate was added in varying amounts to 100-gram samples of soil free of all organic matter, and incubated for several days. On leaching these soil samples with water practically all of the applied nitrate was recovered in the leachings, which indicates that there could be no denitrification or utilization of nitrogen by soil organisms in the absence of sugar or other carbohydrates

When potassium nitrate was added in the same manner, but together with varying amounts of glucose, the nitrates usually disappeared by the third day of incubation. The nitrates in the soil had been changed by the activity of various soil organisms into organic forms of nitrogen and had become part of the living protoplasm of the bodies of these soil organisms. After the available energy materials in the form of sugars or other carbohydrates in the soil have become exhausted, a gradual decomposition of the resulting dead bodies ensues, followed by nitrification processes which convert the protein or organic nitrogen contents of the organisms into nitrates again. In the form of nitrates, this nitrogen may be readily absorbed by growing plants.

The utilization by soil organisms of the applied nitrates and sugars was accompanied by a rapid decrease of the free oxygen dissolved in the overlying water. The rate of utilization of oxygen increased in proportion to the concentration of sugars in the water and soil This indicated that the soil organisms utilized considerable quantities of oxygen in their growth. As the oxygen content of the water decreased there was an observed parallel increase in carbon dioxide content of the solution which indicated that both carbon and oxygen were being utilized by the soil population. In this instance the carbon was derived from the sugar dissolved in the soil solution.

There was an observed increase in acidity of the soil solution and surface water resulting directly from the activities of the soil organisms This reaction would be expected, in part at least, as the result of the concentration of carbon dioxide dissolved in the water forming carbonic acid.

Another factor which accounted for the increased soil acidity was the formation in the soil of large quantities of lactic acid as the result of the activities of soil bacteria. The author states that 30 or 40 per cent of the sugar decomposed was converted into lactic acid. Later on in the process of incubating these soils the amounts of lactic acid decreased and the amounts of acetic acid increased.

The acetic acid was also a direct product of the breaking down of sugars by soil organisms. In this instance the acetic acid had been formed through oxidation of the lactic acid.

Soil samples to which had been added, not glucose, but solely lactic acid, were water-logged and incubated. Soil micro-organisms converted this lactic acid to acetic acid.

In soil samples to which sugar had been added and the samples incubated, not only lactic and acetic acids were determined quantitatively, but also butyric acid was determined as present in relatively large quantities.

Thus the author shows that the sugar added as glucose to the soils incubated in a flooded condition, was eventually converted to lactic, acetic and butyric acids and about 20 to 25 per cent eventually became carbon dioxide. These organic acids, formed by microbial activities in these soil solutions, eventually were converted to lower forms of carbon compounds by certain soil organisms, presumably reaching a final form as carbon dioxide.

Under Hawaiian conditions where water-logging or continued flooding does not normally occur, the decomposition of cane trash and of molasses probably proceeds much more rapidly. The progressive steps in the process of decomposition are doubtless the same while the end result is reached probably much sooner under our conditions of better aeration.

C. C. B.

The Pre-Harvest Sampling of Cane by Refractometer at Ewa Plantation Company

By J. D. Bond

In the hope of materially increasing the accuracy and reliability of our pre-harvest cane samples, particularly in respect to the number of samples to be obtained, studies on the use of the refractometer in sampling cane were instituted in September, 1927.

Technique

An Abbe refractometer equipped with a scale to read directly in per cent solids as applied to sugar solutions, was employed in obtaining the data reported here. The instrument was adjusted to read at 28° C. and was maintained at this temperature, within limits of not over half a degree, by using the water jacket. The adjustment was checked frequently by the use of sugar solutions of known concentrations.

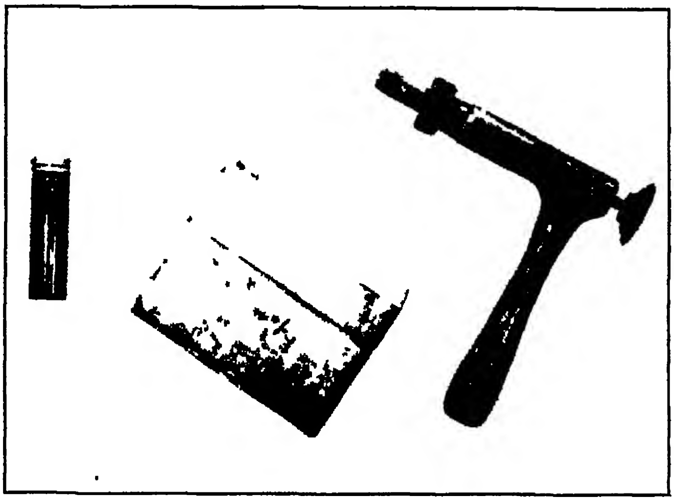


Fig. 1. (From left to right.) Vial used to receive individual borings; tin box to receive borings in lots of a hundred or more; and the sampling "gun" used in this work.

At the start of this work, ordinary cork borers were used to obtain the samples. This was unsatisfactory, however, and our machine shop subsequently developed a small sampling "gun" (Fig. 1) with replaceable cutting tips. The sample plug, about 5/16 inch in diameter and ¾ inch in length, was ejected by a small plunger. Where the solids were determined on the samples individually, each plug was dropped into a small homeopathic vial. Canvas "cartridge" belts were used to receive these vials in field work (Fig. 2). In later work, when a hundred or more

borings constituted a sample, these were collected in tin boxes, 3½ inches long, 1½ inches wide and 2½ inches deep. A close-fitting cover was designed to cut down moisture losses due to evaporation, and when necessary to keep the samples over night the box and cover were taped securely together before being placed on ice.

In the laboratory, the juice from single borings was expressed by a broad-jawed pair of pliers into the same vial, mixed, and a few drops placed on the lower prism of the refractometer. Readings were recorded directly by a small adding machine operated by the analyst. When a hundred or more borings constituted a sample, the laboratory screw press was utilized. Enough juice was expressed in this way for the determination of the polarization.

Fig. 2. Showing the use of the sampling "gun" and the belts used to receive vials.

Point of Sampling on the Stalk

In order to determine that portion of the stalk most suitable for sampling, according to the method outlined above, preliminary work was concerned with the variation of the juice solids from internode to internode throughout the stalk length. The work was done on stalks brought in as regular pre-harvest samples to be crushed in the small sample mill. The fields sampled were from 15 to 18 months old at sampling and were approaching, or at, maturity. A total of 153 stalks were used in this preliminary study. In order to sample only that portion of the stalk coming under the category of millable cane, the first boring for the refractometer was taken at the eighth internode, counting that immediately below the node to which the leaf with the topmost visible dewlap was attached, as the first. In practice, this point was determined by counting down eight leaves and

thus determining the first internode to be sampled. One boring was taken approximately at the center of each internode, dropped into appropriately labelled vials and sent to the laboratory.

The great variation in the number of internodes per stalk, necessitated a grouping of the data by stalks according to the number of internodes. The data have been summarized in Table I, each group including a range of five internodes in the total number noted. Within each of the groups of Table I, variations are found, further, dependent upon the relative maturity of the stalks as evidenced by the concentration of total solids in the juice. Assuming that the arithmetical average of all the determinations per stalk will be roughly proportional to the total expressed juice of that stalk, Tables II and III have been arranged from the data of Table I. In Table II, average solids from 16.00 to 17.99 per cent have been considered; and in Table III from 18.00 to 19.99 per cent, the same grouping of Table I being otherwise followed.

TABLE I

Variation of Stalk Solids by Internodes—Averages According to the Number of Internodes per Stalk

Internodes	27–31	32–36	37–41	42–46	47–51	52–56	57–62
No. Stalks Averaged	5	26	37	31	32	16	6
8	15.48	12.87	13.05	12.09	11.90	12.12	11.33
9	16.14	14.53	14.18	13.37	13.38	13.54	13.08
10	16.98	15.32	15.14	14.34	14.19	14.38	14.20
11	17.12	15.80	15.86	15.11	14.77	14.89	15.02
12	17.12	16.35	16.20	15.64	15.20	15.34	16.20
13	17.90	16.80	16.59	15.93	15.73	15.61	16.72
14	17.96	17.15	16.92	16.31	16.08	16.01	17.03
15	18.18	17.35	17.10	16.46	16.30	16.22	17.05
16	18.52	17.42	17.28	16.64	16.56	16.14	17.15
17	18.46	17.82	17.57	16.70	16.69	16.18	17.40
18	18.58	18.09	17.37	16.77	16.61	16.38	17.65
19	18.32	18.15	17.56	16.82	16.68	16.39	17.87
20	18.46	18.13	17.67	17.04	16.79	16.47	18.02
21	18.62	18.13	17.67	16.86	16.88	16.52	18.08
22	18.70	18.17	17.70	16.98	16.96	16.51	17.85
23	18.90	18.35	17.73	16.93	16.98	16.53	17.72
24	19.06	18.43	17.78	17.02	17.06	16.69	17.78
25	19.10	18.47	17.86	16.99	17.12	16.75	17.68
26	19.40	18.64	18.03	17.04	17.15	16.85	17.72
27	19.34	18.88	18.21	17.26	17.36	17.00	17.88
28	19.64	19.00	18.22	17.35	17.40	16.99	17.77
29		19.15	18.26	17.45	17.61	17.08	17.88
30		19.39	18.39	17.66	17.66	16.99	18.08
31		19.41	18.55	17.65	17.76	17.16	18.05
32		19.51	18.58	17.75	17.81	17.36	17.98
33			18.75	17.74	17.80	17.39	18.27
34			18.86	17.95	17.88	17.29	18.28
35			19.05	17.98	17.93	17.26	18.30
36			19.13	18.11	18.00	17.42	18.57
37			19.16	18.22	18.03	17.48	18.43

Internodes	42–46	47–51	52–56	57–56
38	18.18	18.30	17.69	18.62
39	18.20	18.32	17.94	18.58
40	18.32	18.31	18.06	18.08
41	18.33	18.31	18.03	18.50
42	18.34	18.35	17.96	18.52
43		18.47	18.13	18.45
44		18.44	18.04	18.55
45		18.44	18.19	18.33
46		18.41	18.04	18.47
47		18.45	18.09	18.28
48			18.24	18.13
49			18.26	18.62
50			18.21	18.22
51			18.21	18.43
52			18.21	18.55
53				18.63
54				18.63
55				18.77
56				18.77
57				18.98

5,533 Total Solids Determinations from 153 stalks.

TABLE II

Variation of Stalk Solids by Internodes—Averages According to the Number of Internodes per Stalk—Averages of All Determinations per Stalk Ranging from 16.00 to 17.99 Per Cent Solids

Internodes	32–36	37–41	42–46	47–51
No. of Stalks Averaged	11	13	9	11
Average All Stalks	17.06	16.87	16.79	16.90
8	11.96	12.38	11.43	11.65
9	13.51	13.82	13.04	12.89
10	14.57	15.10	14.43	13.73
11	15.01	15.48	15.12	14.43
12	15.57	15.70	15.81	14.65
13	15.94	15.98	16.00	15.23
14	16.41	16.18	16.42	15.56
15	16.46	16.41	16.53	15.65
16	16.52	16.59	16.69	15.95
17	17.05	16.93	16.72	16.19
18	17.37	16.82	16.86	15.99
19	17.80	17.16	17.06	16.15
20	17.78	17.02	17.18	16.32
21	17.85	16.86	16.68	16.35
22	17.92	16.88	16.90	16.53
23	18.03	16.90	16.87	16.68
24	18.00	17.02	16.83	16.91
25	18.08	17.21	16.84	16.85
26	18.25	17.31	16.60	17.01
27	18.49	17.45	16.83	17.25
28	18.56	17.58	16.84	17.37
29	18.58	17.57	17.06	17.44
30	18.78	17.71	17.34	17.53
31	18.95	17.84	17.34	17.74
32	19.15	17.88	17.54	17.94
33		18.16	17.57	17.81
34		18.25	17.76	17.97
35		18.47	17.74	18.01
36		18.68	17.94	18.08
37		18.85	18.12	18.10
38			17.99	18.47
39			18.12	18.59
40			18.26	18.41
41			18.46	18.42
42			18.66	18.65
43				18.69
44				18.60
45				18.81
46				18.70
47				18.69

TABLE III

Variation of Stalk Solids by Internodes—Averages According to the Number of Internodes per Stalk—Averages of All Determinations per Stalk Ranging from 18.00 to 19.99 Per Cent Solids

Internodes	32–36	37–41	42–46	47–51
No. of Stalks Averaged	12	13	11	5
Average All Stalks	19.85	18.81	18.68	18.61
8	13.41	14.50	13.85	11.96
9	15.53	15.34	15.08	13.94
10	16.56	15.90	16.05	14.50
11	17.13	17.20	16.85	15.44
12	17.61	17.53	17.15	16.08
13	18.28	18.15	17.68	17.02
14	18.53	18.57	18.07	17.44
15	18.83	18.73	18.15	17.70
16	18.82	18.86	18.36	18.20
17	19.15	19.26	18.45	18.40
18	19.51	18.68	18.33	18.34
19	19.33	18.78	18.30	18.44
20	19.31	19.06	18.46	18.50
21	19.30	19.11	18.53	19.02
22	19.33	19.22	18.61	19.14
23	19.53	19.30	18.65	19.14
24	19.54	19.25	18.81	19.04
25	19.73	19.23	18.76	19.20
26	19.79	19.47	18.89	19.12
27	20.01	19.68	19.20	19.56
28	20.16	19.57	19.45	19.54
29	20.37	19.48	19.50	19.82
30	20.57	19.69	19.65	19.56
31	20.42	19.81	19.58	19.66
32	20.43	19.77	19.62	19.66
33		19.88	19.65	19.64
34		19.95	19.93	19.68
35		20.12	19.94	19.64
36		20.13	19.97	19.62
37		20.09	20.02	19.72
38			20.00	19.84
39			19.94	19.90
40			19.91	20.14
41			19.70	20.00
42			19.66	19.88
43				19.76
44				19.76
45				19.58
46				19.44
47				19.30

There is evidently a tendency, though not entirely consistent, for the longer stalks to have lower solids in the juice at the corresponding internode, counting from the top down; or, in other words, the shorter stalks have the higher solids, at the corresponding internode from the top than the longer stalks, both yielding approximately the same normal juice. In the longer and more mature stalks, the

solids reach a maximum a few internodes above the base after which the solids decrease toward the base. In the less mature stalks the solids increase progressively toward the base

In order to gain a general idea of the variation of solids from internode to internode, all the data of Table I have been averaged, by internodes for 15 internodes from the top down and again from the base up. These averages are given in Table IV.

TABLE IV

Internode Averages—Per Cent Solids in Juice

Internode Number Top to Bottom	Bottom to Top	From Top Toward Bottom	From Bottom Toward Top
8	1	12.50	18.81
9	2	13.96	18.76
10	3	14.75	18.74
11	4	15.39	18.62
12	5	15.84	18.57
13	6	16.26	18.47
14	7	16.60	18.37
15	8	16.79	18.28
16	9	16.94	18.24
17	10	17.13	18.15
18	11	17.16	18.06
19	12	17.24	18.00
20	13	17 35	17.94
21	14	17.35	17.86
22	15	17.39	17.76

The rapid increase in solids from the top down, until about the twentieth internode (Fig. 3), is evident. The decrease in solids from the base toward the top appears gradual, though, as previously noted, in the longer, more mature stalks, a maximum point is reached in this range, followed by a decrease.

In selecting a point of sampling, it is essential to designate a portion of the stalk throughout which the rate of change of solids by internodes is not excessive. Obviously, we cannot consider that portion of the stalk immediately below the top, until about the twentieth joint. It is not, furthermore, practicable to go much beyond this point under our conditions since the tracing of stalks imbedded in trash and overlain with other stalks is difficult. On the other hand, if we choose to use the base of the stalk as a point of reference, the number of internodes to be counted must be as small as possible for the same reason and yet great enough to overstep the point of maximum solids found in the longer, more mature stalks. Arbitrarily, we have chosen the tenth internode from the base and the twentieth from the top for the comparisons of the following table, the averages being obtained without respect to the stalk length. Stalks of less than 32 internodes have been excluded.

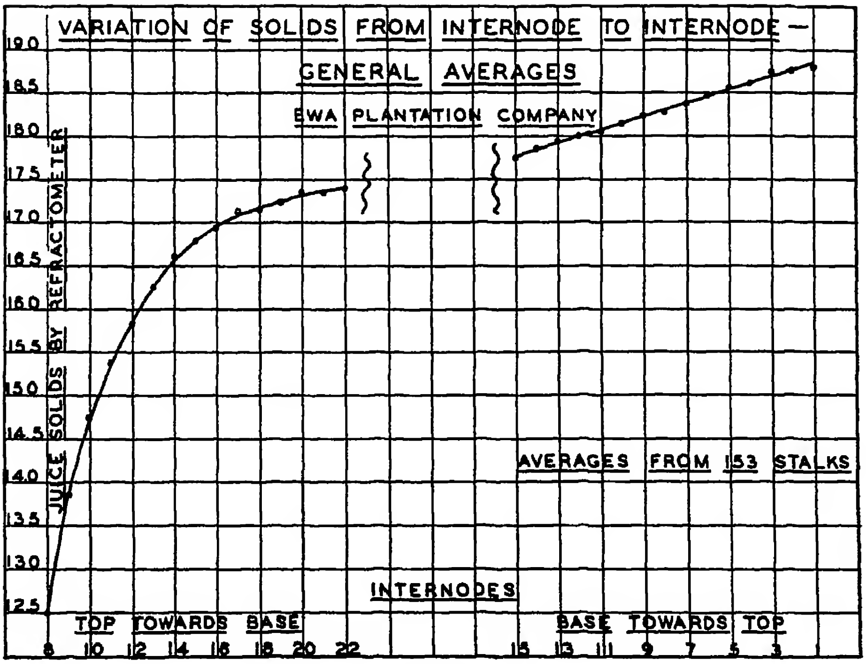


Fig. 3

TABLE V

Comparisons of the Solids of the Twentieth Internodes from the Top and the Tenth from the Bottom of the Stalk With the Average Solids of All Internodes

Average Solids All Internodes			Solids		Diff.: Average to	
Group	Average	No. Averaged	20th Internode from Top	10th Internode from Bottom	20th Internode	10th Internode
14.0 to 15.9	15.05	32	14.89	16.11	+0.16	—1.06
16.0 to 17.9	16.91	51	17.02	17.87	—0.11	—0.96
18.0 to 19.9	18.69	48	18.81	19.52	—0.12	—0.83
20.0 to 21.9	20.66	12	20.73	21.42	—0.07	—0.76

The over-all range in the variation of the average differences is practically the same in both cases. There appears to be no clear advantage from these data in the use of one or the other point of sampling or presumably of any other point, consistently followed between those specified. In order to avoid the possibility of the samplers taking borings near the top, it was decided to limit our work to the tenth internode from the bottom.

Variation of Solids Within Internodes

In order to determine the variation of juice solids within the tenth internode from the bottom, data were collected on five equally spaced points of sampling. A boring was taken at each node and three borings equally spaced between the nodes. The summarized data are as follows:

TABLE VI

Variation of Solids Within Internodes

Group Averaged	No. Averaged	Upper Node	2	3	4	Lower Node
14.0—15.9	13	15.58	15.25	15.15	15.40	15.98
16.0—17.9	19	16.67	17.16	17.07	17.20	16.89
18.0—19.9	27	18.41	19.21	19.03	19.04	18.39
20.0—21.9	14	19.76	20.74	20.81	20.67	19.99
All	73	17.71	18.25	18.17	18.23	17.58

In all cases except the lowest group where the opposite is true, the nodes yielded appreciably lower solids than the points in the internode. The three points sampled in the internode show a variation close enough to be disregarded in work of this nature.

Method of Sampling: Entirely Through the Stalk or Part Way

Inasmuch as the diameter of cane stalks vary, the question arose as to whether the data might be appreciably influenced by boring entirely through the stalk as against boring only to the depth of the "gun" tip as ordinarily used. The collected data on this point follow, the comparative borings being taken from the same internode.

TABLE VII

Boring Through the Stalk Compared With Boring Part Way as Affected by Stalk Circumference

			Solids of Samples Taken		
Group Averaged†	Average Circumference	No. Averaged	Through Stalk	To Depth of Tip	Difference
2.0—2.9	2.6	5	21.76	21.74	0.02
3.0—3.9	3.5	20	18.92	18.93	—0.01
4.0—4.9	4.2	27	18.43	18.31	0.12

No differences large enough to be of influence in this method of sampling are to be noted.

Deterioration of Samples

As a necessary step in the development of our technique, studies were attempted on the keeping qualities of the borings. In the first series of data (Table VIII), three borings were taken per internode, solids being determined from one boring immediately, one after 12 hours in the laboratory and the third after 24 hours. Each boring was kept in its individual vial, which was closed with the cork lined screw top provided. In the second series, two samples only were taken from each internode concerned, the comparisons being then between a control and 12 hours in the laboratory, and a control and 24 hours in the laboratory.

* Based on solids of mid-point or No. 8 above.
† Circumference in inches.

TABLE VIII

Effect of Delays on Determination of Solids

	No. Averaged	Solids at Sampling	Solids 12 Hours Later	Solids 24 Hours Later
First Series	42	18.62	18.50	18.69
Second Series (a).	99	18.27	18.12	.
(b) . .	100	19.37	. . . .	19.36

A more detailed study of the data than is shown in Table VIII indicates a tendency for the solids to decrease slightly in 12 hours followed by slight increase. In any event the differences are small enough to be negligible in this work.

Data on the deterioration of the juices when the borings were collected in numbers and the juice expressed in one operation, follow the outline given above. The averages of 10 comparative tests are reported below:

TABLE IX

Deterioration of Juices from Borings

	At Sampling	12 Hours Later	24 Hours Later
Solids	17.39	17.19	17.23
Pol'n	14.88	14.60	14.42
Purity	85.57	84.93	83.69

The steady decrease in polarization and purity is at once apparent. The purity drop after 24 hours is almost 2 points, which is certainly excessive.

Attempts at using preservatives, including formalin, toluol, ammonium hydroxide and ethyl ether were unsatisfactory. The use of refrigeration was effective, however, as is shown in Table X, which gives the average of 12 tests.

TABLE X

Effect of Refrigeration on Deterioration of Juices from Borings

	At Sampling	Control— 24 Hours Later	Refrigeration— 24 Hours Later
Brix	17.18	17.03	17.27
Pol'n	14.47	14.05	14.57
Purity	84.23	82.50	84.37

Whenever necessary to delay the analyses of the samples in our work, these were placed on ice immediately on arrival at the laboratory.

Comparison of Solids Determined from Averages of Analyses of Individual Borings and from Numbers of Borings Expressed in One Operation

The amount of laboratory work demanded to obtain the solids of large numbers of individual borings led us to express the juice from a hundred or more borings in the screw press and to analyze this juice for solids and polarization. In order to compare the data obtained from these two procedures, two borings were taken from each internode sampled, one of these being placed in a glass vial and the

other being dropped into a tin box, into which all such borings from a given field location were placed. The summarized data on this point are given below:

TABLE XI

Comparison of Solids Determined from Individual Analyses of Borings and from Expressed Juice

Solids— Groups Averaged	No. per Group	Solids by Refractometer: Average of Individual Analyses	Solids by Refractometer: Expressed Juice	Difference
17.0—17.9	5	17.51	17.57	—0.06
18.0—18.9	11	18.58	18.70	—0.12
19.0—19.9	5	19.41	19.67	—0.26
20.0—20.9	1	20.23	20.17	+0.06
All	22	18.60	18.73	—0.13

Considering the variations found in pre-harvest data, the difference between these two procedures is negligible though the solids of the expressed juices evidently run slightly higher, as a rule, than the average of individual analyses The saving in time and labor by expressing the juice from a large number of borings at one time as against the observation of hundreds of individual samples, is obvious.

Purity of Juices from Borings Compared With Crusher Juice

At this point, it may be well to summarize our data comparing the purity of the juices expressed from the borings taken with the sampling gun and the purity of crusher juice. Fields immediately previous to harvest were sampled by travelling across the areas according to a designated direction previously indicated on the field maps and taking a boring at the tenth internode from the base, the stalks being selected at random, about every 15 feet. With such data we give the weighted average crusher juice purity at harvest.

TABLE XII

Purity of "Refractometer" Juices Compared With Average Crusher Juices by Fields

Purity Groups Based on Crusher Juice	No. of Fields	Purity of Juices: Crusher	Purity of Juices: Refractometer	Difference
82.0—82.9	2	82.79	90.03	7.24
83.0—83.9	3	83.70	90.53	6.83
84.0—84.9	5	84.43	91.31	6.88
85.0—85.9	5	85.57	92.09	6.52
86.0—86.9	8	86.51	92.31	5.80
87.0—87.9	5	87.38	91.96	4.58
88.0—88.9	9	88.44	92.29	3.85
89.0—89.9	1	89.33	93.39	4.06
All	38	86.34	91.87	

Based on averages of "individual" analyses.

The purities of the juices from the pre-harvested samples are relatively insensible to wide differences in the purities of crusher juices and are evidently of little value in estimating crusher juice purities. For this work, then, we will confine ourselves to a consideration of solids only.

Solids of the Tenth Internode Compared With Sample Mill Juices of Same Stalks; and With Crusher Juices from Experiment Plots

The first step in attempting to apply this method of sampling to practical use was to compare the solids of the tenth joint with the Brix of our sample mill juice. The work was done on samples of five stalks each, each stalk being sampled for the refractometer at the tenth internode from the base and the same stalks then being crushed in the sample mill. Experiment plots were also sampled immediately previous to harvest, 25 borings per watercourse plot, and this compared with the crusher juice samples taken for each plot.

TABLE XIII

Comparison of Solids—"Refractometer" Sampling With Sample Mill and With Crusher Juices

Solids Groups—Based on Refractometer	Refractometer and Sample Mill				Refractometer and Crusher			
	No.	Ref. Solids	Brix	Diff.	No.	Ref. Solids	Brix	Diff.
12.0—12.9	6	12.31	13.27	—0.96				
13.0—13.9	8	13.56	14.00	—0.44	1	13.84	15.13	—1.29
14.0—14.9	21	14.56	14.67	—0.08	2	14.82	15.24	—0.42
15.0—15.9	27	15.50	15.79	—0.29	2	15.32	15.05	+0.27
16.0—16.9	35	16.53	16.33	+0.20	7	16.56	16.85	—0.29
17.0—17.9	30	17.46	17.11	+0.35	15	17.61	17.43	+0.18
18.0—18.9	18	18.55	17.77	+0.78	19	18.43	18.20	+0.23
19.0—19.9	7	19.55	18.81	+0.74	13	19.42	18.85	+0.57
20.0—20.9	6	20.36	19.70	+0.66	7	20.27	19.09	+1.18
21.0—21.9	3	21.41	19.97	+1.44	1	21.16	20.00	+1.16

Apparently a tendency is present for the refractometer solids of the samples to be lower than the Brix of the sample mill juices and of the crusher juices below 16 per cent solids; and to be higher above this. The data are not adequate enough and fluctuate too widely to allow a generalization which can be applied to practical work with any assurance. Rather than attempt to accumulate further data on this point, we proceeded directly to the pre-harvest sampling of fields and to the comparisons between pre-harvest juice and crusher juice analyses by fields.

Pre-Harvest Sampling With Refractometer and Sample Mill Compared

During the crops of 1928 and 1929, a total of 88 fields were sampled, both for the refractometer and for the sample mill. A comparison between the two methods of sampling, according to the established procedure in each case, is thus afforded:

TABLE XIV

Comparison of Crusher Juice Brix and Pre-harvest Solids

Brix Groups Based on Crusher Juice	No. of Fields	Solids: Crusher	Solids: Sample Mill	Solids: Refractometer	Difference: Crusher to: Sample Mill	Difference: Crusher to: Refractometer
16.50—16.99	2	16.90	18.28	17.15	—1.38	—0.25
17.00—17.49	8	17.30	17.96	17.51	—0.66	—0.21
17.50—17.99	13	17.74	17.98	18.00	—0.24	—0.26
18.00—18.49	14	18.34	18.66	18.54	—0.32	—0.20
18.50—18.99	15	18.77	18.87	19.03	—0.10	—0.26
19.00—19.49	21	19.26	18.93	19.25	+0.33	+0.01
19.50—19.99	13	19.67	19.28	19.41	+0.39	+0.26
20.00—20.49	2	20.04	19.68	20.03	+0.36	+0.01
Group Averages						
16.50—18.99	52	18.10	18.43	18.34	—0.33 ±0.48	—0.24 ±0.39
19.00—20.49	36	19.45	19.09	19.36	+0.36 ±0.43	+0.10 ±0.37
All	88	18.65	18.70	18.75	—0.05 ±0.52	—0.10 ±0.41

There is apparently a break at about 19 Brix, below this point the pre-harvest solids in both methods being higher than the crusher; and above, lower than the crusher. The averages of these two large groups of data are shown in Table XIV. The probable errors of the mean differences are appreciably greater than the differences themselves, indicating that they are of no significance. The considerable fluctuation of the data is, by this means, also apparent.

It was originally intended to estimate the purity of crusher juice by referring the solids determined by refractometer, to the Brix-purity curve for crusher juice. Since the Brix-purity relationship varies with the season of harvest, a detailed application of the method might have been elaborated. It is obvious, however, that fluctuations so large as to show a probable error of about ±0.4, preclude such a study. It will be of some value, however, to compare the pre-harvest procedures on the basis of purity, estimating the crusher juice purity, in the case of the work with the refractometer, by reference to the general Brix-purity relationship of crusher juice as given by our data of the crops of 1924 to 1928, inclusive.

TABLE XV

Brix-Purity Relationship of Crusher Juice

Brix Range	No. Samples	Brix	Pol'n	Purity
14.0—14.4	33	14.22	11.44	80.45
14.5—14.9	72	14.74	11.95	81.07
15.0—15.4	231	15.24	12.46	81.76
15.5—15.9	469	15.73	13.07	83.09
16.0—16.4	1063	16.23	13.58	83.67
16.5—16.9	1770	16.71	14.09	84.32
17.0—17.4	2588	17.21	14.68	85.30
17.5—17.9	3253	17.70	15.18	85.76
18.0—18.4	3611	18.20	15.71	86.32
18.5—18.9	3621	18.70	16.23	86.79
19.0—19.4	2923	19.19	16.70	87.02
19.5—19.9	1930	19.67	17.17	87.29
20.0—20.4	943	20.17	17.58	87.16
20.5—20.9	326	20.64	17.98	87.11
21.0—21.4	112	21.17	18.42	87.01
21.5—21.9	35	21.60	18.71	86.62

Interpreting the pre-harvest refractometer solids of the 88 fields previously considered, we obtain the following purity data:

TABLE XVI

Comparison of Crusher Juice and Pre-harvest Purities

Purity Groups Based on Crusher Juice	No. of Fields	Purity Crusher	Sample Mill	Refracto-meter	Differences—Crusher to: Sample Mill	Refractometer	Corrected Sample Mill
82.0—82.9	3	82.85	85.76	86.44	—2.91	—3.59	+0.06
83.0—83.9	3	83.70	88.28	86.91	—4.58	—3.21	—1.61
84.0—84.9	6	84.46	88.49	86.82	—4.03	—2.36	—1.06
85.0—85.9	11	85.53	89.61	86.16	—4.08	—0.63	—1.11
86.0—86.9	24	86.49	89.31	86.45	—2.82	+0.04	+0.15
87.0—87.9	20	87.40	90.00	86.60	—2.60	+0.80	+0.37
88.0—88.9	19	88.45	90.77	86.98	—2.32	+1.47	+0.65
89.0—89.9	2	89.50	92.61	87.16	—3.11	+2.34	—0.14
Averages	88	86.71	89.68	86.22	—2.97 ±0.84	+0.49 ±1.06	

As practically all of the estimated "refractometer" purities lie between 86 and 87 irrespective of the purity of crusher juice, this procedure is obviously of little value in pre-harvest estimates of crusher juice purities. The difference of 2.97 between the purities of the sample mill and of the crusher juices is significant as shown by the probable error. Applying this difference as a correction, the data of the sample mill still remains far from accurate.

The probable errors of the differences between the Brix of crusher juice and the Brix of sample mill juice as compared with refractometer solids of Table XIV indicate that the refractometer procedure is not inferior to the sample mill in so far as the estimation of the Brix of crusher juice is concerned. Inasmuch as the Brix of crusher juice is in general correlated with the purity of crusher juice, the determination of the total solids of pre-harvest samples by the refractometer offers one method of following the ripening of cane. Some typical examples of the use of this procedure in comparison with the use of the sample mill follow:

TABLE XVII

Pre-harvest Sampling by Refractometer and Sample Mill Compared

Field	Refractometer Date	No.	Av. Solids	Sample Mill Brix	Purity	Q. R.	Date	Crusher at Harvest Brix	Purity	Q. R.	Date
W	Jan. 12	150	15.18	16.10	86.21	9.80	Jan. 13				
	Feb. 23	127	16.36	18.00	90.28	8.10	Feb. 21				
	Mar. 26	148	17.54	18.13	90.57	8.00	Mar. 28				
	April 30	149	18.28	19.82	90.01	7.39	April 30	17.89	87.03	8.67	May 3–16
X	Jan. 18	149	18.03	17.53	88.41	8.64	Jan. 18				
	Mar. 6	297	18.80	18.94	91.21	7.60	Mar. 6				
	Mar. 28	150	19.39	19.35	91.16	7.41	Mar. 28	19.43	88.99	7.69	April 5–9
Y	Jan. 14	150	14.14	12.73	69.36	18.80	Jan. 16				
	Mar. 3	149	16.01	16.47	85.61	9.69	Feb. 25				
	April 5	122	18.76	16.97	87.39	9.08	Mar. 31				
	May 5	137	18.52	19.20	90.26	7.59	May 14				
	June 16	150	19.30	18.93	89.65	7.79	June 16				
	July 10	150	19.19	18.30	89.78	8.04	July 10				
	Aug. 6	101	19.33	20.13	90.56	7.20	Aug. 6				
	Aug. 24	104	20.14	18.77	88.28	8.07	Aug. 24	19.61	86.69	7.97	Aug. 27–Sept. 1
Z	Jan. 17	122	14.80	15.63	82.53	10.90	Jan. 16				
	Mar. 5	153	16.73	15.83	84.46	10.33	Feb. 25				
	April 4	123	17.71	17.73	88.16	8.56	Mar. 31				
	May 7	161	18.76	19.37	90.50	7.49	May 14				
	June 16	172	18.58	19.67	91.00	7.31	June 15				
	July 10	147	19.00	20.33	91.34	7.03	July 10				
	July 21	108	19.58	18.63	87.33	8.28	July 21	19.06	86.73	8.19	July 23–28

It is, of course, desirable to obtain some idea of the relative purity in pre-harvest sampling. If, however, the purity data are not desired, this procedure becomes considerably less expensive. Furthermore, inexpensive pycnometers may be used in place of the refractometer, expressing the juice from one or two hundred sample lots in one operation.

Frequency Data

As a part of this work, it was desired to obtain fairly comprehensive data on the solids characteristics of the stalk population of fields approaching maturity in order to gain some idea of the problem involved in the pre-harvest sampling of cane. Such data should afford some foundation for further work on the development of pre-harvest sampling technique.

In Table XVIII, the sampling data from over 22,000 individual stalks are assembled. These data were available from the sampling of the fields of the 1929 crop through the month of March. The averages are given according to the months of harvest and of sampling. The data of individual fields falling either above or below the group average by one or two classes have been adjusted by moving the frequency data up or down one or two classes. Thus, if the group average fell into the 17.0 to 17.9 class and the field in question showed an average falling into this same class, the data were used without modification. If, however, the field average fell into the next lower class or 16.0 to 16.9 solids, then the entire frequency of that field was moved up one class for the summary. This procedure adjusts the data to a distribution about the group mean but does not destroy the relative shape of the curve.

Frequency Data in Per Cent by Months of Sampling and of Harvest—Solids of the Tenth Internode by Refractometer

Months of Sampling	2.0–2.9	3.0–3.9	4.0–4.9	5.0–5.9	6.0–6.9	7.0–7.9	8.0–8.9	9.0–9.9	10.0–10.9	11.0–11.9	12.0–12.9	13.0–13.9	14.0–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–18.9	19.0–19.9	20.0–20.9	21.0–21.9	22.0–22.9	23.0–23.9	24.0–24.9
Fields Harvested December																							
May–June	....	....	....	....	....	....	....	....	....	....	0.30	1.01	2.78	5.56	8.43	17.54	21.31	20.83	13.67	8.77	1.45	0.37	....
August	....	....	....	....	....	....	....	0.21	0.90	1.07	3.53	3.21	5.25	9.81	11.36	17.49	18.88	16.72	8.11	2.54	0.85	0.08	....
September	....	....	....	....	....	....	....	0.23	1.70	1.79	2.72	2.87	6.17	7.38	13.40	15.09	21.14	16.79	8.06	1.75	...	....	....
October	....	....	....	....	....	..	0.31	0.66	1.18	1.15	3.38	3.68	4.80	8.08	12.72	17.11	16.18	17.60	8.12	4.01	0.14	....	....
November	...	....	....	....	....	0.16	0.29	0.59	1.77	1.20	1.30	2.41	5.39	5.94	14.16	15.93	18.89	20.35	7.95	2.09	0.70	0.60	0.20
December	....	....	....	0.10	0.10	0.11	0.39	0.28	0.21	0.38	0.48	1.36	2.56	4.49	9.41	15.10	19.93	20.58	16.31	6.65	1.44	0.11	...
Fields Harvested January																							
May–June	....	....	....	....	....	....	....	....	0.34	0.52	0.81	2.02	6.02	8.94	17.71	19.85	17.88	14.57	7.51	3.21	0.73	0.08	....
August	....	....	....	....	...	....	....	....	0.74	1.14	1.54	3.68	7.10	9.11	12.95	19.20	17.48	14.10	8.17	3.72	0.98	....	...
September	....	....	....	....	....	....	....	0.81	1.88	2.17	3.35	2.37	6.29	9.41	12.46	17.56	18.30	12.59	8.46	3.64	0.32	...	...
Oct.–Nov.	....	....	....	....	....	....	0.77	0.80	1.20	1.81	3.19	2.22	5.79	6.18	12.83	13.98	16.31	16.63	11.91	5.78	0.30	0.31	....
Dec.–Jan.	....	0.07	0.12	....	0.29	0.32	0.35	0.28	0.84	1.47	1.57	3.09	3.84	6.10	14.67	20.59	22.33	15.93	5.75	1.92	0.40	0.07	....
Fields Harvested February																							
May–June	....	....	....	....	....	....	....	....	0.46	0.22	1.20	1.82	4.92	13.85	17.57	21.68	19.47	11.22	5.82	1.38	0.38	....	....
August	....	....	....	....	....	....	....	....	0.16	1.17	1.77	4.15	5.68	5.08	16.02	19.15	15.04	15.40	8.40	3.30	0.67	....	....
Sept.–Oct.	....	....	....	....	....	....	0.06	0.39	1.21	2.83	2.18	3.09	4.55	6.13	11.47	16.80	21.16	15.42	8.80	5.16	0.69	0.05	....
December	....	....	....	....	0.12	0.11	0.22	....	0.42	0.97	1.61	1.76	4.01	7.55	13.75	21.41	22.01	13.91	7.16	4.15	0.72	0.12	....
January	....	....	0.12	0.09	0.25	0.08	0.23	0.81	0.68	0.88	1.81	2.98	4.92	10.21	13.38	21.20	19.96	13.53	7.43	1.36	0.00	....	....
February	....	....	....	0.10	0.13	0.56	0.28	0.11	0.40	0.84	0.55	1.88	2.67	4.02	8.05	12.70	18.48	25.07	16.59	6.40	1.16	....	....
Fields Harvested March and April																							
May–June	....	....	....	....	....	....	....	....	....	....	0.98	1.94	5.92	9.61	19.34	19.57	16.87	14.14	7.44	3.33	0.87	...	....
August	....	....	....	....	....	....	....	0.10	0.41	1.26	2.30	3.94	4.85	10.00	12.00	14.25	21.34	16.08	6.77	3.78	0.83	0.20	....
September	...	....	....	....	....	....	0.52	2.30	2.64	3.85	3.59	5.21	7.14	10.26	12.17	18.54	10.90	10.24	2.57	0.55	0.23	....	....
January	0.08	....	0.08	0.50	0.50	0.35	1.12	1.25	1.49	2.23	2.39	5.26	10.55	12.75	16.30	18.21	15.77	8.49	2.62	0.55	....	....	....
February	0.06	0.10	0.15	0.19	0.25	0.10	0.24	0.89	0.52	1.15	2.87	2.99	5.36	8.08	13.85	17.08	20.21	12.02	8.37	3.08	0.84	....	....
Mar.–April	....	....	0.06	....	0.05	0.13	0.41	0.49	0.30	0.84	0.92	1.16	2.31	4.02	7.56	11.14	15.30	20.57	20.10	11.34	3.08	0.17	0.05

A surprisingly large variation in the solids of individual stalks at the tenth internode from the base is evident (Fig. 4) and offers some explanation for the difficulties encountered in obtaining accurate pre-harvest samples. For this reason, too, we rely on the trend of our sampling data from month to month rather than accept the data as they stand at any one sampling

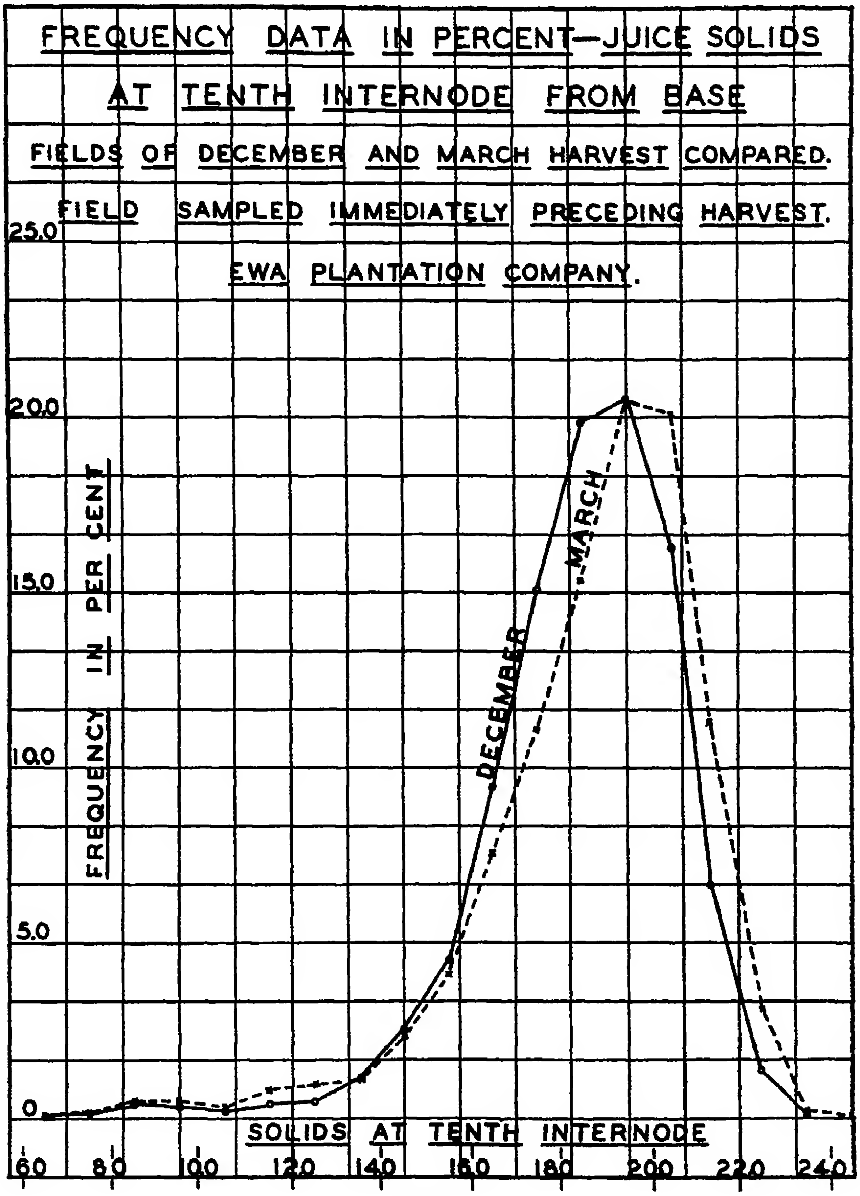


Fig. 4

TABLE XIX

Variation of Solids by Refractometer of Adjacent Stools—H 109

		Line 1					Line 2				
	Stool No.	No. Stalks*	Average†	Highest	Lowest	Suckers	No. Stalks*	Average†	Highest	Lowest	Suckers
Field 10A	1	10	16.45	19.0	15.0	..	3	15.27	15.6	15.0	....
June 27, 1929	2	2	13.25	16.5	10.0	..	6	13.38	16.6	11.6	....
Age 11.9 Months	3	2	13.35	13.9	12.8	..	6	17.00	18.0	16.0	....
Plant	4	6	15.78	17.0	14.6	..	2	16.50	17.5	15.5	....
	5	9	14.41	18.0	11.1	9.8	3	17.40	18.0	16.4	....
	6	2	13.85	14.1	13.6	..	2	14.75	16.2	13.3	....
	7	4	15.15	16.5	13.7	..	6	17.00	19.2	13.0	....
	8	2	14.10	15.3	12.9	..	10	14.87	17.6	11.1	6.9
	9	7	14.74	10.1	11.0	..	10	13.27	15.2	10.0	4.0
	10	4	17.23	19.3	13.9	..	9	15.11	17.5	12.4	....
	11	6	14.70	17.0	12.7	..	2	12.40	13.0	11.8	....
	12	7	16.16	20.1	12.2	..	7	13.64	15.3	11.6	8.4 & 9.7
	13	10	18.17	20.6	16.2	..	5	13.80	14.5	13.1	....
	14	2	16.95	17.3	16.6	..	2	12.40	12.4	12.4	....
	15	13	17.93	20.2	15.4	7.9	6	11.90	12.9	11.0	3.2, 6.4 & 7.3
	16	10	15.93	17.5	13.9	..	2	10.80	....	....	7.8
	17	4	16.30	17.9	14.7	..	6	13.97	16.6	10.6	....
	18	9	15.69	17.9	13.7	..	4	14.25	14.5	14.0	5.5 & 9.1
	19	5	15.38	17.0	12.9	..	10	14.88	17.0	13.8	....
	20	1	16.00	....	....	..	9	12.39	14.6	10.6	4.0 & 9.0
	21	9	16.54	18.5	13.9	..	4	12.23	13.8	11.2	....
	22	6	14.92	18.0	11.9	6.5	5	12.88	14.1	11.9	5.4
	23	3	15.40	16.7	13.3	..	4	13.10	14.3	11.0	7.6
	24	..	....	....	....	..	3	13.37	14.1	12.4	....

* Including suckers.
† Excluding suckers.

This variation is also shown in a small test on the variation between adjacent stools in plant cane about a year old. (Table XIX.) The stalks were sampled at the tenth internode consecutively in line. The variations between the stools are so great as to render the use of this sampling procedure in variety work of doubtful application under local conditions.

SUMMARY

1. A pre-harvest sampling technique involving the use of the refractometer has been attempted.

2. This technique has been compared with the usual sample mill procedure in field trials. For the estimation of crusher juice Brix, the refractometer method of sampling is not inferior to that of the sample mill. The method is not applicable to the estimation of crusher juice purity.

3. The progress of cane ripening can be followed in a general way through pre-harvest sampling for the determination of solids only.

4. Frequency curves indicate a great variation in the total solids of the stalk population of fields approaching maturity. This is true also of individual stools in plant cane about a year old.

Pollen Studies II

Germination of Sugar Cane Pollen in Culture Media

By D. M. Weller

In 1926, there appeared in *The Hawaiian Planters' Record* (4) a paper entitled "Progress Report of Sugar Cane Pollen Studies." In that paper was given a quantitative method of germinating sugar cane pollen by limiting the factors conducive to pollen germination to two factors, viz., relative humidity and temperature. A brief review was also given there of the methods used by different investigators from different parts of the sugar cane world whereby the determining of viability of sugar cane pollen had been attempted. It is apparent from that review that, in the minds of these investigators, the criterion of viability was the actual formation of pollen tubes by the pollen grains. Also the desirability of securing quantitative data was suggested.

A statement occurs there to the effect that trials at this Station in recent years to germinate cane pollen in culture media were unsuccessful. With the thought that it would be interesting to know just what these trials were, a careful search of the project files of this Station was made. Two reports were found, the first one by Dr. L. O. Kunkel and the second one by C. C. Barnum.

Review of Attempts to Germinate Sugar Cane Pollen at This Station

The following is taken from the *Monthly Letter* of this Experiment Station for the period from November, 1922, to January, 1923:

> Sugar cane pollen differs from that of many plants in that it will not germinate on artificial media. Dr. Kunkel reports experiments as follows:
>
> During the past month, an effort was made to germinate pollen grains of sugar cane in artificial media. Fresh pollen of the varieties D 1135 and H 109 was dusted into plates containing the following media: nutrient agar, dextrose agar, cane sugar agar, potato agar, bean agar, oat agar, synthetic agar, Biejerinck agar and water agar. The test was repeated several different times, but in no case did a single grain germinate. With the exception of synthetic agar, the pollen remained plump and in apparently good condition on all of the different media. Unsuccessful germination tests were also made in hanging drops of water, and in 2 per cent sugar solution. Germinations were, however, obtained by dusting fresh pollen onto stigmas of sugar cane and papaya. Because of the large size and smooth surfaces they possess, papaya stigmas are especially well suited for germinating cane pollen. Some germinating grains were scraped from papaya stigmas and placed in iodine solution in permanent mounts.
>
> A considerable quantity of D 1135 pollen was collected from day to day and brushed onto the stigmas of Uba, growing at the Federal Experiment Station. It is hoped that this will give rise to D 1135-Uba seedlings. Anthers of Uba, so far as examined, do not produce fertile pollen. The ovaries seem to be normal.

In the *Monthly Letter* for December, 1924, H. Atherton Lee writes as follows:

> The best tests of the viability of pollen are the actual formation of pollen germ tubes, and such germination was secured fairly uniformly on Petri dishes in which drops of 5

per cent glucose solution were placed. Germination did not take place in the drops of the glucose solution, but in the condensed moisture on the plates between the drops.

Under date of March 20, 1926, Mr. Barnum reports the results of his trials to germinate cane pollen on agar plates. These trials were made during November and December of 1924, and are the trials mentioned above by Mr. Lee.

Mr. Barnum says in his report:

An attempt to germinate the pollen in Petri dishes on the surfaces of various concentrations of agar proved unsuccessful. The pollen grains usually remained turgid and of normal size during periods of three to six or more days on all sterile poured plates of agar. No germination was noted. The plates were maintained at room temperature and the concentrations of the agar jelly were as follows: agar and water only in the following percentages: 1.50, 2.00, 3.00, 4.00 and 5.00 per cent; nutrient agar of 30 per cent, and nutrient agar, 3.00 per cent plus 2.00 per cent sucrose. For these germination studies on agar both H 109 and D 1135 tassels were shaken over separate plates at 6, 7, 8, 9 A.M. on November 8, November 9, and November 11, 1924. The tassels used for this study were kept in sulphurous acid solutions in the new greenhouse.

A little further on in Mr. Barnum's report occurs a record of attempts to germinate cane pollen in varying concentrations of sugar solutions He writes:

An attempt to germinate pollen grains on microscope slides on which thick cane sugar syrup had been partially dried in separate drops was attempted. Pollen was dusted over such slides and they were then placed in moist chambers. Pollen taken at 11:30 A.M. November 18, failed to germinate both on the plate surface and in the syrup. Further studies were made using sucrose and dextrose syrups separately. Negative results were obtained in cane sugar or sucrose, but slight germination was noted in dextrose.

At this point, no explanation of the failures contained in these two reports will be attempted but a comment upon them will be offered further on.

Purpose of the Present Studies

It is the practice in the cane-breeding work in Hawaii to bring together male and female tassels by placing them with their cut ends in vessels of sulphurous acid. It is desirous to know in this work: (1) what effect different concentrations of sulphurous and other acids (including the ones now used as common practice) have on the percentage of viability of pollen produced by tassels so treated, (2) how the percentage of viability of pollen from cut tassels compares with that of pollen from growing tassels on successive days after their initial pollen shed (the cut tassels to be cut on the day of their first flowering), (3) how long pollen grains remain viable after being shed, (4) how effective methods for preserving pollen in viable form (so that early flowering varieties may be crossed with late flowering varieties) may be in case such methods are developed, and (5) how the percentages of viability of the different varieties used compare.

Only a standardized method of germinating cane pollen can answer these questions.

The purpose of these studies was, therefore, to standardize a method for the securing of quantitative data in regard to the above five points.

Methods and Materials

In 1927, Dutt and Ayyar (3) reported the obtaining of high percentages of germination of pollen from a great number of cane varieties. This method consisted of using a culture medium of 26 per cent sucrose plus 0.7 per cent agar as "hanging drops" in culture slides. A thin layer of the medium was spread on a coverslip and dusted with pollen. This coverslip was then inverted and sealed with vaseline over the cavity in the culture slide. Drops of the medium were placed in the bottom of the cavity of the hollow ground slide to prevent drying of the medium on the coverslip. Later the percentage of germination of the pollen was determined by examining these coverslips under the microscope.

This method of Dutt and Ayyar was tried using a number of media because it was surmised that under conditions which prevail in Hawaii and with pollen from the Hawaiian varieties of cane a higher or lower concentration of sugar or agar in the medium might be necessary for successful germination, or that different concentrations might be required for pollen from different varieties of cane. The contents of these media are shown in Table I:

TABLE I

Medium No.	Agar Grams	Sucrose Grams	Water Ml	Agar	:	Sucrose
1	0.17	24	100	1	:	141.1
2	0.35	25	100	1	:	71.4
3	0.70	26	100	1	:	37.1
4	1.00	27	100	1	:	27.0
5	1.30	28	100	1	:	21.5
6	1.70	29	100	1	:	17.0
7	2.00	30	100	1	:	15.0

Commercial granulated sugar, "Difco" Standardized, a Bacto-agar made by the Digestive Ferment Company of Detroit, Michigan, and distilled water were used in making up these media.

Except where stated to the contrary, the pollen used in these tests was taken from tassels which had been cut the previous day and kept over night with their cut ends in an approximate 0.03 per cent solution of sulphurous acid. In order to minimize the influence of variation of pollen from single tassels, three tassels of the same variety were used at a time so that the pollen used in the tests was a composite sample rather than pollen from a single tassel. Only tassels cut the previous day were used because it has been shown that the percentage of viable pollen from tassels kept in sulphurous acid decreases very rapidly after the tassels are cut (4).

Results

Using the above methods and materials ten preliminary tests were made with the results shown in Table II:

TABLE II

Showing the percentages of germination of pollen from several varieties of cane obtained with different media (shown in Table I) in hanging drops in culture slides at room temperature.

Medium No.	U. S. 4163	D 1135	U. S. 4163 (1)	S. W. 3 (2)	28 4363 (2)	20 S 16 (2)	Maka-weli 3	26 Q 2079	H-27 (2)	D 1135
1	0.0	0.0	0.0	0.0	3.7	0.0	10.0	0.0	0.0	0.0
2	5.2	0.0	12.5	0.0	0.0	0.0	5.0	0.0	4 [illegible]	0.0
3	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	7.5	0 0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(1) Tassels cut two days previously.

(2) Pollen taken from tassels on the same day they were cut.

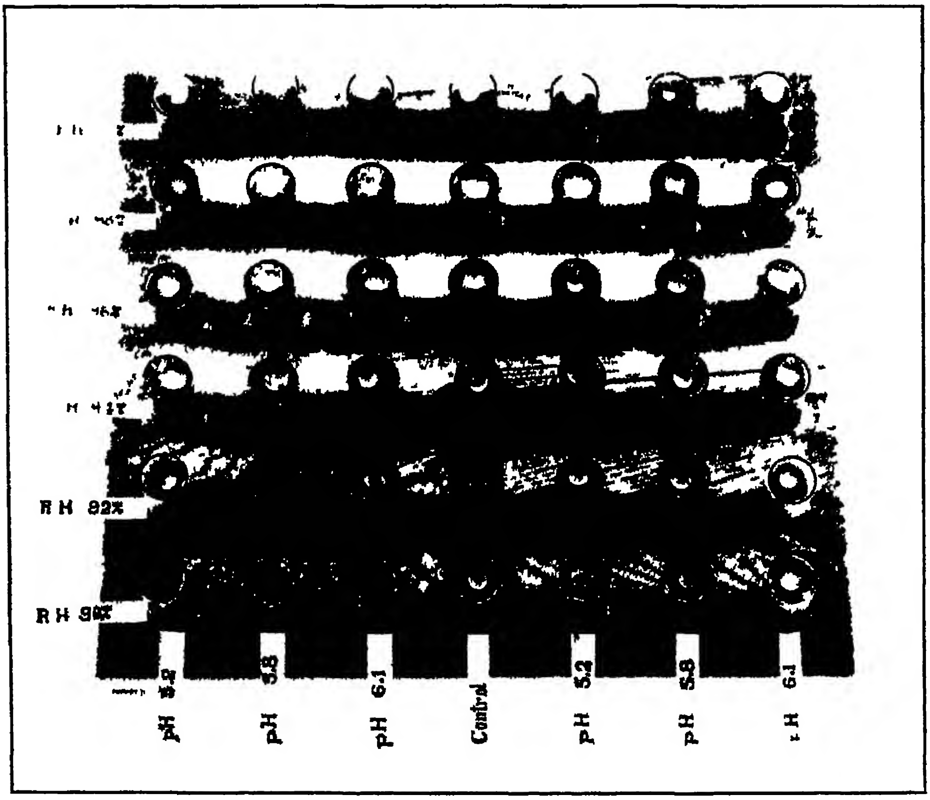


Fig. 1. Showing vials on which are sealed cover glasses with hanging drops of culture media on them. The relative humidities of the air surrounding these drops of culture media are controlled by solutions of sulphuric acid of different concentrations in the vials. Such boards holding the vials were substituted for the shelves of constant temperature ovens operating at different temperatures.

These data seemed to indicate that medium No. 2 held greater possibilities than the others and was, therefore, after several more preliminary tests recorded below, used in future experiments.

Method Using Sulphuric Acid Solutions in Sealed Chambers to Control Relative Humidity

In the next test, all of the media of Table I were used and the factor of relative humidity was introduced. Vials with ground tops were partly filled with different concentrations of sulphuric acid. Drops of agar were placed on coverslips and dusted with pollen. These coverslips were then inverted and sealed with vaseline on the vials containing the sulphuric acid solutions In each sealed chamber the air over the sulphuric acid solutions had a constant relative humidity dependent upon the concentration of the sulphuric acid solution in that vial and the temperature at which it was maintained (5). (See Fig. 1.) Coverslips without drops of agar were also used, the pollen simply being caught on the dry glass and treated in the same way as those which had drops of agar on them. These are called "controls."

The sulphuric acid solutions were of such concentrations that the relative humidities of the air in the sealed chambers above them were 100, 98, 96, 94, 92 and 90 per cent.

This method was used with pollen from the variety H 27 with the results shown in Table III:

Table III

Showing percentages of germination obtained with H 27 pollen in the media shown in Table I with the constant relative humidity indicated and at room temperature.

Medium No.	Relative Humidity 100%	98%	96%	94%
1	0.0	0.0	0.0	0.0
2	2.1	4 0	5.8	3.8
3	0.0	1.2	4.5	0.5
4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0
Control	0.8	0.0	0.0	0.0

Here, again, medium No. 2 gave the highest per cent of germination (5.8 per cent) and, at this temperature, 96 per cent was the optimum relative humidity. The percentage of germination in the culture media significantly exceeded that of the controls.

In the next test, the factor of relative humidity was kept in operation, and the factors of temperature and pH values of the media were introduced. This test was run with vials containing sulphuric acid as described in the preceding one. Because the work of 1925 (4) indicated that 22.0° C. was the optimum tempera-

ture, the vials were placed in an incubator at that temperature. Medium No. 2 was used and the pH values were adjusted to 5.2, 5.4, 6.2, 6.9 and 7.7. Relative humidities of 100, 98, 96 and 94 per cent were maintained as before. Controls were also run. Pollen from the variety H 456 was used. The result of this test was that not a single germination occurred. Two controls for each humidity also showed negative germination. We are at a loss for an explanation of this negative germination (unless it were tassel variation) for tests with pollen from this variety later on in the season at 20.0° C., and 23.0° C. resulted in germinations as high as 5.5 and 8.8 per cent respectively.

This test was repeated using again pollen from H 456 with both medium No. 2 and medium No. 3, but at 24.5° C. These results are shown in Table IV:

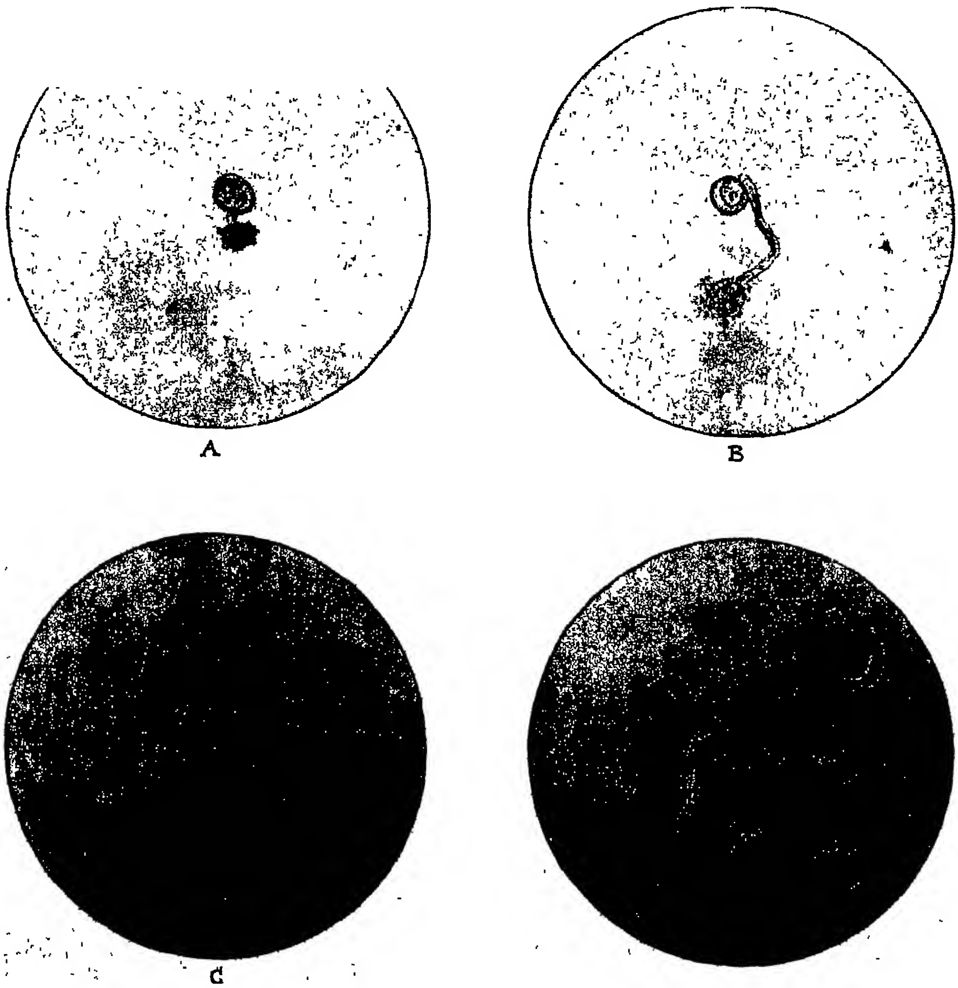


Fig. 2. Showing pollen grains of the variety H 456 germinating at a relative humidity of 96 per cent, in medium No. 2 with a pH value of 5.2, and at 27.0° C. (A), at 25.5° C. (B), at 24.5° C. (C), and at 23.0° C. (D). x140.

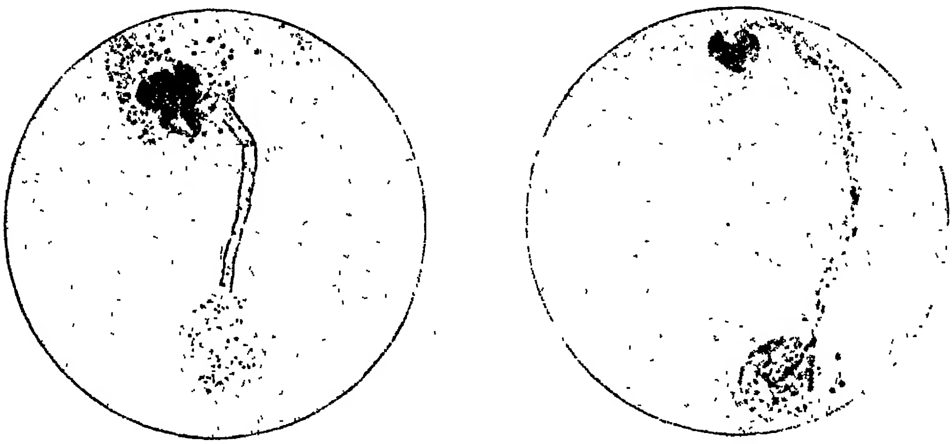
TABLE IV

Showing the percentages of germination of H 456 pollen on media No. 2 (M2) and No. 3 (M3) at 24.5° C. and at the pH values and the relative humidities indicated.

RELATIVE HUMIDITY

	100%		98%		96%		94%	
pH	M 2	M 3	M 2	M 3	M 2	M 3	M 2	M 3
4.7 (1)	0.0	0.5	0.4	1.2	0.0	3.6	0.0	2.2
5.2	3.3	0.0	3.9	1.7	5.5	4.8	5.4	2.8
5.8	1.2	0.9	2.9	0.9	2.6	2.1	1.1	1.5
6.1	3.5	0.0	1.7	0.6	2.4	0.0	2.8	0.4
6.4 (2)	2.9	2.8	1.5	0.0	1.2	0.0	3.7	0.0
Control (3)	0.3		0.9		0.0		0.0	

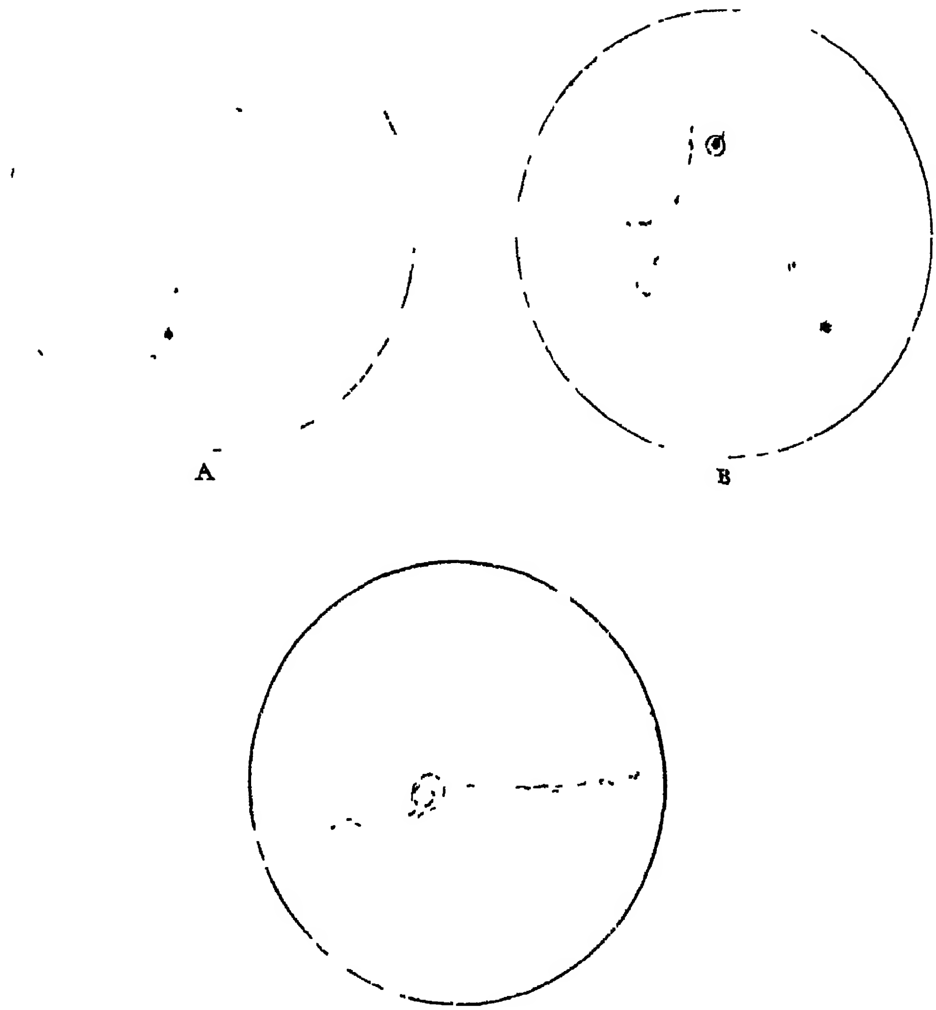
(1) This pH for medium No. 3 was 4.5.
(2) This pH for medium No. 3 was 6.5.
(3) Average of 4 vials for each relative humidity.



A B

Fig. 3. Showing germinating pollen grains of the variety D 1135 just before the thin-walled swellings at their distal ends ruptured. A took place at room temperature in the bottom of a Petri dish, in the cover of which were placed five drops of water on small bits of filter paper. B took place in a sealed vial of sulphuric acid solution at a relative humidity of 96 per cent and at a temperature of 22.0° C. x140.

From these data it is seen that at the temperature of this test (24.5° C.) as high as 5.5 per cent germination occurred. It is further seen that the maximum germinations for both media occurred at the pH value of 5.2 and at 96 per cent relative humidity. Here again the maximum percentage of germination for medium No. 2 was greater than that for medium No. 3, being 5.5 per cent for medium No. 2 and 4.8 per cent for medium No. 3. At this temperature the tubes of germinating pollen grains in medium No. 2 at 96 per cent relative humidity and with a pH value of 5.2 were characterized by being relatively longer than those secured at this temperature in 1925 without culture media. (Fig. 2, C, and Fig. 3, A.) Frequently it happened that double tubes developed from a single pollen



A B C

Fig. 4. Showing pollen grains of the varieties H 109 (A) and D 1135 (B and C) producing double pollen tubes. These germinations took place in medium No. 2 adjusted to a pH value of 5.2, at a relative humidity of 96 per cent, and at a temperature of 23.0° C. x70.

grain or that a single pollen tube branched. (Fig. 4.) These pollen grains were unstained and the negatives unretouched.

This test was run again at 25.5° C. and at 27.0° C. with the results shown in Tables V and VI:

TABLE V

Showing the percentages of germination on media No. 2 and No. 3 of H 456 pollen at 25.5° C. and at the pH values and relative humidities indicated.

RELATIVE HUMIDITY

pH	100% M 2	100% M 3	98% M 2	98% M 3	96% M 2	96% M 3	94% M 2	94% M 3
4.7 (1)	0.0	0.2	0.0	1.7	0.0	0.8	0.8	0.7
5.2	1.2	0.0	1.7	0.0	3.4	0.6	0.6	0.2
5.8	0.5	0.0	0.6	1.8	0.8	1.3	1.3	2.9
6.1	0.0	2.8	2.0	0.6	0.8	0.0	0.0	0.2
6.4 (2)	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Control (3)	0.0		0.0		0.0		0.0	

(1) This pH for medium No. 3 was 4.5.
(2) This pH for medium No. 3 was 6.5
(3) Average of 4 vials for each relative humidity.

From data in Table V, it is seen that again the maximum germination occurred in medium No. 2 at a pH value of 5.2 and at 96 per cent relative humidity. This was 3.4 per cent while at 24.5° C. it was 5.5 per cent. The maximum for medium No. 3 was 2.9 per cent occurring at a relative humidity of 94 per cent and at a pH value of 5.8. (Fig. 2, B.)

TABLE VI

Showing the percentages of germination on media No. 2 and No. 3 of H 456 pollen at 27.0° C. and at the pH values and relative humidities indicated.

RELATIVE HUMIDITY

pH	100% M 2	100% M 3	98% M 2	98% M 3	96% M 2	96% M 3	94% M 2	94% M 3
4.7 (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	
5.8	0.0	0.0	0.0	0.5	0.0	0.0	0.0	
6.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	
6.4 (2)	0.0	0.0	0.0	0.3	0.0	0.3	0.0	
Control (3)	0.1		0.0		0.4		0.0	

(1) pH 4.5 for medium No. 3.
(2) pH 6.5 for medium No. 3.
(3) Average of 4 vials for each relative humidity.

At this temperature the maximum per cent of germination for medium No. 2 was 0.8 per cent occurring again at a pH value of 5.2 but at 100 per cent relative humidity; for medium No. 3 it was 0.5 per cent occurring at 98 per cent relative humidity and at a pH value of 5.8. These percentages are not only less than those obtained at 24.5° C. but are also less than those obtained at 25.5° C. (Fig. 2, A.)

The results of these three tests (Tables IV, V, VI) indicate that, for pollen of the variety H 456, the optimum medium is medium No. 2 (shown in Table I); that the optimum pH value of the medium is near 5.2; that the optimum relative humidity is near 96 per cent, and that the percentage of germination decreased as the temperature was increased from 24.5° C. to 25.5° C. and 27.0° C. successively. Because the maximum germination under these conditions was but 5.5 per cent,

it was thought that this percentage might be increased by the action of some enzyme or combination of enzymes. It was planned, therefore, to try certain amylolytic enzymes and later some of the proteolytic enzymes.

Trials With Diastase

A series of experiments was next run, using medium No. 2 alone, and with sputum added, at the rate of 7 ml. to 375 ml. of agar. This latter medium was designated as M2S. The relative humidities, 100, 98, 96 and 94 per cent were maintained as before. The pH values of the two media (M 2 and M 2 S) were adjusted to 5.2, 5 8 and 6.1. Pollen from the varieties H 456 and D 1135 was used. The culture slide method described above was run along with them.

The results of the first of these experiments are shown in Table VII:

Table VII

Showing the effect on the percentages of germination of H 456 pollen of diastase added to medium No. 2 in the form of sputum, at the indicated pH values and relative humidities, and at 27.0° C.

	pH						
	5.2		5.8		6.1		
R. H.	M 2	M 2 S	M 2	M 2 S	M 2	M 2 S	Control (1)
100%	0.0	0.0	0.0	0.0	0.0	3.2	0.0
98%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
94%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cult. Slds.	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(1) Average of two vials for each humidity.

There was a slight indication here of beneficial effect of the diastase action of the sputum, for 3.2 per cent occurred in the medium to which the sputum was added while in that to which none was added no germinations occurred. The data of Table VI also showed that at 27.0° C. the per cent of germination of this pollen was very low, viz., 0.8 per cent.

The results of a similar test run with pollen from H 456 and from D 1135 at 26.0° C. are shown in Table VIII.

Table VIII

Showing the relative percentages of germination of pollen from the varieties H 456 and D 1135 in media with and without sputum at the indicated relative humidities and pH values and at 26.0° C.

pH

R. H.	5.2 M 2 H456	5.2 M 2 D1135	5.2 M 2 S H456	5.2 M 2 S D1135	5.8 M 2 H456	5.8 M 2 D1135	5.8 M 2 S H456	5.8 M 2 S D1135	6.1 M 2 H456	6.1 M 2 D1135	6.1 M 2 S H456	6.1 M 2 S D1135	Control
100%	0.8	9.0	0.5	0.0	3.1	5.4	0.0	0.0	1.2	0.0	0.0	12.5	0.0
98	0.0	2.1	0.0	6.2	0.4	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	12.2	0.4	0.0	0.0
94	0.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cult. Slds.	0.0	3.8	2.5	0.0	2.4	0.0	0.4	0.0	1.7	4.8	2.1	0.0	

Trials With Taka-Diastase

Having this indication that the addition of diastase in the form of sputum to the medium stimulated germination, Taka-diastase was added to medium No. 2 after the agar was melted and ready for use, i.e., immediately before each test. This medium is designated as No M2D10. The results of the first trial are shown in Table IX:

Table IX

Showing the effect of Taka-diastase (added to medium No. 2 at the rate of one drop to 10 ml. of agar) on the percentages of germination of pollen of the variety H 456 at the relative humidities and pH values indicated and at 23.0° C.

pH

R. H.	5.2 M 2	5.2 M 2 D10	5.8 M 2	5.8 M 2 D10	6.1 M 2	6.1 M 2 D10	Control
100%	7.5	0.0	0.0	0.0	0.0	0.0	0.0
98%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96%	0.0	0.0	8.5	9.0	6.7	0.0	0.0
94%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cult. Slds.	2.7	0.0	0.0	0.0	0.0	0.0	

It is apparent from the data contained in Table IX that fewer germinations occurred in the medium to which the Taka-diastase was added. This test was repeated under the same conditions of temperature, humidity and pH value of medium, using pollen from the variety D 1135 with similar results. The question arises from the results of these two tests as to whether this inhibitive effect was the result of the direct action of the diastase on the pollen grains themselves, or was the result of the presence of dextrose into which some of the sucrose was changed by the action of the diastase, or was simply the result of an improper amount of diastase. By adding a smaller amount of Taka-diastase (one drop to 20 ml. of the agar), there were considerably more germinations in this medium than in the preceding test. When one drop of 10 per cent Taka-diastase was added to the same amount of agar, a still higher per cent of germination resulted but in each case so far these per cents were less than those in the medium without the diastase.

To separate test tubes, each containing 10 ml. of medium No. 2 was added 1 drop of 2, 4, 6 and 8 per cent Taka-diastase. These dilutions of Taka-diastase were made with sterile distilled water. Pollen of the variety H 456 was used. The test was run in the same manner as the preceding ones with the results shown in Table X:

Table X

Showing the effect on the percentages of germination of H 456 pollen of the additions of Taka-diastase to medium No. 2 at the rate of 1 drop of 2, 4, 6 and 8 per cent as against no diastase (M2); the pH value of the medium being 5.2; the temperature, 23.5° C.; and the relative humidity being 100 per cent and 98 per cent.

R. H.	M 2	2% T-d (1)	4% T-d	6% T-d	8% T-d	Controls (2)
100%	0.9	1.9	2.8	4.8	5.0	0.3
98%	0.8	5.1	6.7	4.5	1.3	0.0
Cult. Slds.	1.3	0.0	3.5	1.7	1.2	

(1) T-d=Taka-diastase.
(2) Average of 3 vials for each humidity.

There is a definite indication from the data of Table X that stimulation of germination resulted from additions of Taka-diastase. In every case where the diastase was added, there was an increased per cent of germination over that occurring in the medium No. 2. Furthermore, the percentages of germination increased as the per cent of diastase added increased. The failures of some and the inhibitive effect of others of the preceding tests with Taka-diastase may, therefore, be explained on the basis of unsuitable amounts having been added.

Trials With Raw Sugar

It has been found by Brink (2) that higher percentages of pollen germination occur on culture media made with commercial granulated sugar than on those made with C. P. sucrose (2, p. 292).* The explanation of this is suggested by the fact that certain substances, perhaps organic, present in the commercial product are absent in the chemically pure sucrose. It was decided, therefore, to carry this idea one step further in the direction of the impure sugar. Raw sugar which had been washed once in the milling process was, therefore, used in making up a medium. This medium was made up in the same way in every respect as medium No. 2 and is designated as M2R. A test was made with H 456 pollen using this medium and medium No. 2, the results of which are shown in Table XI.

Table XI

Showing the percentages of germination of H 456 pollen obtained in a medium made with raw sugar (M2R) as compared with medium No. 2 at 20° C. and at the relative humidities and pH values indicated.

Brink's paper available to the author at this point.

pH

R. H.	5.2 M 2	5.2 M 2 R	5.8 M 2	5.8 M 2 R	6.1 M 2	6.1 M 2 R	Control (1)
100%	3.5	0.0	5.5	0.0	1.7	0.0	0.0
98%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96%	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Cult. Slds.	0.0	0.0	0.0	0.0	0.0	0.0	

(1) Average of four vials for each humidity.

It is evident from these figures that raw sugar did not increase pollen germination but definitely inhibited it. Several tests were run at higher temperatures with this medium but with similar results.

The pH Values of the Media Adjusted With Various Acids

In the next test the pH values of agar were adjusted by the use of three different acids: sulphuric (M2S), phosphoric (M2P), and malic (M2M). Agar No. 2 was used. The pH values were adjusted to 5.2, 5.8 and 6.1. Pollen of the variety H 456 was used and the temperature was 24.0 C. The results of this test are shown in Table XII.

Table XII

Showing the effects on the percentages of germination of H 456 pollen of agars having their pH values adjusted by sulphuric, phosphoric, and malic acids to the indicated reactions, at the indicated relative humidities, and at 24.0° C.

pH

R. H.	5.2 M2S	5.2 M2P	5.2 M2M	5.8 M2S	5.8 M2P	5.8 M2M	6.1 M2S	6.1 M2P	6.1 M2M	Control (2)
100%	9.5	0.0	0.0	6.2	4.3	10.0	0.0	0.0	2.5	5.8
98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cult. Slds.	16.6	0.0	0.0	0.0	0.0	0.0	16.6	0.0	0.0	

(2) Average of three vials for each humidity.

It is seen from the data of Table XII that when the pH value of the medium was adjusted to 5.2 with sulphuric acid the percentage of germination was 9.5 at 100 per cent R.H. and 16.6 in the culture slides. When the same adjustment was made with phosphoric and malic acids no germinations resulted. When the pH value was adjusted to 5.8 with malic acid, higher percentages of germination were obtained than when this adjustment was made with sulphuric acid or phosphoric acid. When the reaction of the medium was adjusted to 6.1 with sulphuric acid and malic acid, the percentages of germination were respectively 16.6 in the culture slides, and 2.5 at 100 per cent relative humidity. These tests were repeated several times with similar results. When the reaction of the medium was adjusted

to 6.1 with these three acids the results were sometimes in favor of one and sometimes in favor of another.

Comparison of Germinations on Successive Days After Tassels Were Cut

In the next three tests, a comparison was made of the percentages of germination of pollen from tassels kept with their cut ends in sulphurous acid for one, two and three days. Six tassels of the variety H 456 were used for this purpose. The pollen used in these tests was a composite sample of all six tassels. The pH values of agar No. 2 were adjusted to 5.2, 5.8, and 6.1 with sulphuric, phosphoric and malic acids. Both the culture slide and the vial methods were used. For the vials the percentages recorded in Table XIII represent the averages of two counts. The relative humidity in the vials was maintained at 100 per cent. The temperature was 24.0 C. The results of these three tests are shown in Table XIII.

Table XIII

Showing the relative percentages of germination of H 456 pollen on the first three days after the tassels were cut, composite samples of pollen from six tassels being used, at the pH values indicated, at the relative humidity of 100 per cent and in culture slides, and at 24.0° C. The pH values were adjusted by sulphuric acid (M2S), phosphoric acid (M2P), and malic acid (M2M).

	pH								
		5.2			5.8			6.1	
		Day			Day			Day	
R. H.	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
				M 2 S					
100%	3.0	16.6	0.0	6.4	5.3	0.0	6.6	2.2	0.0
Cult. Slds.	5.4	8.2	0.0	9.6	8.8	0.0	15.0	6.1	0.0
				M 2 P					
100%	0.6	2.2	0.0	2.3	6.9	0.0	0.0	0.3	0.0
Cult. Slds.	2.2	1.0	0.0	8.4	10.9	0.0	1.6	0.0	0.0
				M 2 M					
100%	1.3	2.4	0.0	2.6	7.5	0.0	1.2	4.2	0.0
Cult. Slds.	5.7	0.0	0.0	6.9	11.6	0.0	6.4	3.6	0.0

From the data of Table XIII it is seen that on the first day the highest per cent of germination in the vials was 6.6 and occurred in medium M2S adjusted to a pH value of 6.1; in the culture slides it was 15.0 per cent and likewise occurred in M2S at a pH value of 6.1. On the second day the highest per cent of germination in the vials was 16.6 occurring in M2S at a pH value of 5.2; in the culture slides, it was 11.6 occurring in M2M at a pH value of 5.8. On the third day, no germination occurred at all.

These results agree with those previously reported (4), namely, that the percentage of germination of pollen from cut tassels decreases rapidly on successive days after the tassels are cut.

Here again at a pH value of 5.2 the highest per cent of germination occurred in the medium adjusted with sulphuric acid. At a pH value of 5.8 it occurred

in the medium adjusted with malic acid and, at a pH value of 6.1, the highest per cent of germination occurred, in the medium adjusted with sulphuric acid. Whenever the pH values were adjusted with phosphoric acid the percentages of germination have been consistently lower than when the adjustments were made with either sulphuric acid or malic acid.

TEMPERATURE

The data shown in Tables VI, VIII, V, IV, IX, and XI seem to indicate that temperature has a decided influence on the percentages of germination of sugar cane pollen. These tables show the percentages of pollen of the variety H 456 germinating on medium No. 2 at temperatures ranging from 27.0° C. to 20.0° C. The maximum percentage of germination of each of these tables is shown in Table XIV.

TABLE XIV

Showing the maximum percentage of germination (Tables VI, VIII, V, IV, IX, and XI) of H 456 pollen obtained on medium No. 2 at temperatures ranging from 27.0° C. to 20.0° C.

Per Cent Germination	Temperature of Oven ° C.	Air Temperature at Time of Pollen Shed ° C.	No. of ° C. Oven Was Above or Below Air Temperature	Table
0.8	27.0	21.1	+5.9	VI
3.1	26.0	23.6	+2.4	VIII
3.4	25.5	23.8	+1.7	V
5.5	24.5	23.6	+0.9	IV
8.8	23.0	22.2	+0.8	IX
5.5	20.0	22.7	—2.7	XI

It is seen from the above table that the maximum percentage of germination was 8.8 per cent and occurred at 23.0° C. Previous tests without agar indicated that the optimum temperature was somewhere near 22.0° C. (4). It is seen further from Table XIV that there is a correlation between the percentage of germination and the temperature at which the germination occurred. However, when the difference between the temperature of the air at which the pollen was shed and the temperature at which the germination of the pollen took place is taken into consideration, it is seen that there exists another correlation which is equally tenable.

While the minimum germination (0.8 per cent) occurred at 27.0° C., there was as much as 5.9° C. difference between the temperature of the air when the pollen was discharged from the anthers and the temperature at which germination of this pollen took place in the oven. The maximum germination (8.8 per cent) occurred at 23.0° C. The difference between this temperature and that of the air when the pollen was shed was only 0.8° C. In other words, the maximum percentage of germination occurred at the temperature differing the least from that of the temperature of the air when the pollen was shed and the minimum percentage occurred when these two temperatures differed the most.

Discussion

As to why the requirements for the germination of sugar cane pollen are so exacting in regard to an artificial medium, it is not easy to explain. According to Brink (2): "A source of no little annoyance and perplexity to those who have attempted to cultivate pollen artificially has been the bursting of pollen and pollen tubes. No satisfactory explanation of this phenomenon has as yet been brought forward." He cannot agree with Van Tieghem, Molisch, Lidforss, and others that the bursting of pollen grains and pollen tubes "is not related to the osmotic force of the surrounding medium," and says that their conclusion "that it is not an unbalanced osmotic condition . . . has been based on the assumption that the protoplasmic surface of the pollen grain acts as a semi-permeable membrane to sugar solutions. There is no good evidence to show that this, in general, is the case." He feels rather that the evidence "favors the view that it is largely an osmotic phenomenon" and then brings forward considerable evidence to show that "pollen tubes of many species will grow readily on sugar solutions varying widely in concentration" and arrives at the conclusion that "the cell membranes of the pollen grain and its tube are, or become, permeable to cane sugar, and that the final result as far as osmotic pressure is concerned is the same as though the surrounding medium were water. Perhaps osmotically active substances are produced within the cell, bringing it into equilibrium with the particular concentrations of sugar without. If this were so, we should expect a well-defined optimum concentration of sugar for early growth, above which the pollen would plasmolyze and below which, if the wall could not sustain the pressure, the tubes would burst."

From the fact that in the media used in these tests bursting occurred in the low concentrations and plasmolysis in the high ones it would seem that plasmolysis and bursting were due to osmotic pressure and that the cell wall of the sugar cane pollen at least is semi-permeable. Anthony and Harlan found that barley pollen burst in low concentrations of sugar solutions and plasmolyzed in high ones (1).

In previous tests also (4) there were indications that the pollen tube is semi-permeable for evidence of osmotic pressure is seen in the swelling of the pollen tubes (Fig. 3), which can hardly be explained on the basis of imbibition alone. It is seen further that the walls of these tubes become thinner at their distal ends as is evidenced by the position of the swellings and final ruptures.

Medium No. 1 was of semi-liquid consistency (*sol*). Medium No. 2 was slightly more viscous and of a consistency that might be considered either a *sol* or a *jel*. Medium No. 3 was more viscous than medium No. 2, or a semi-solid (*jel*), and continuing on through media Nos. 4, 5, 6 and 7 there was a gradation of increasing viscosities.

This gradation of viscosities in the series of media was due principally to increased percentages of agar although it was influenced also by increased percentages of sugar. Being emulsoids it is seen that, as the disperse phase is increased in this series, the amount of dispersion medium in each was relatively decreased. This means that, beginning with medium No. 1 and continuing on through the series, in the last one of this series the structure of the original emulsoid was partially, if not completely, reversed and that in medium No. 1, for example, the concentration of the sugar solution available to the pollen grain and tube was higher

than the percentage indicated in Table I and that between each medium and the succeeding one there was a greater increase in sugar concentration than is indicated by the figures of Table I.

When using sulphuric acid solutions in sealed chambers to control relative humidity the concentrations of the media used would either remain the same or change according to whether the hanging drops took up or gave off moisture as influenced by the relative humidity of the air surrounding them. Thus the germination of pollen grains, if lying on the surface of the medium, would not only be influenced directly by the relative humidity of the air with which they were in contact, but also it would be influenced indirectly by any resultant change in the concentration of agar and sugar of the medium used; if lying beneath the surface, it would be influenced only indirectly.

The fact that in medium No. 2 the maximum per cent of germination occurred and that the tubes of these pollen grains at the optimum temperature, humidity, etc., were characterized by exceptional length (Fig. 2, D) indicates that this medium resulted in the optimum rate of osmosis or imbibition. As the pollen tube developed and advanced through the medium, the sugar solution (dispersion medium) was absorbed by osmosis or imbibition. If, as in medium No. 2, let us suppose, this absorption *rate* was balanced with the *rate* of increasing capacity of the *growing* tube, and if the actual amount of food so absorbed in this particular concentration of sugar solution met the requirements for *growth* of the developing pollen tube, the maximum per cent of germination and the maximum tube length would result. This rate of absorption would not only depend upon the osmotic pressure due to the concentration of sugar in the dispersion medium but also the structure of the interlacing phases of the emulsoid would control the amount of the disperse phase with which the growing tube would come in contact. If, in the case of medium No. 1, we had a *sol* with concentrated droplets of the disperse phase scattered through the dispersion medium so that the absorption rate was greater than the rate of increasing capacity of the growing tube, bursting would result even before a tube was actually developed by the pollen grain. If, as in media Nos. 4 to 7, the process of osmosis or imbibition was reversed, plasmolysis resulted.

Summary

From the results of the preceding experiments together with those previously reported, from those reported by Dutt and Ayyar, and others, it is evident that the germination of sugar cane pollen is dependent upon a nice balance of retroreactive physical and chemical factors.

An attempt is made in these experiments to standardize a method of germinating sugar cane pollen by controlling the concentration of sugar and agar in hanging drops of culture media, the pH value of the media, the relative humidity and the temperature of the air surrounding the hanging drops, and by the addition of enzymes to the culture media.

Quantitative data are presented to show that, when a series of culture media having a gradient of viscosities due to increasing concentrations of sugar and agar were used, a particular medium consistently gave the maximum percentage of germination. These percentages consistently exceeded those of the controls.

An optimum relative humidity of 96 per cent and an optimum temperature of approximately 23.0° C. were demonstrated.

While there was a correlation between temperature and percentage of germination there also existed a correlation between percentage of germination and the difference between the temperature of the air when the pollen was shed and the temperature at which germination occurred.

When the pH values of the media were adjusted with sulphuric, phosphoric, and malic acids, better results were obtained with sulphuric acid. The optimum pH value was approximately 5.2.

Definite stimulation of germination was demonstrated by the addition of definite amounts of Taka-diastase to the culture medium.

The percentage of germination of pollen from cut tassels decreased from 16.6 per cent on the second day to 0.0 per cent on the third day after cutting.

Sincere thanks are due to W. T. McGeorge, formerly of the chemistry department, for his painstaking adjustment of the pH values of the media used in these experiments, and to Dr. A. J. Mangelsdorf for supplying the tassels.

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Sugar Prices

96° Centrifugals for the Period March 17 to June 13, 1930

Date	Per Pound	Per Ton	Remarks
Mar. 17, 1930	3.625¢	$72.50	Philippines, 3.64, 3.61.
" 18	3.61	72.20	Philippines, Porto Ricos, Cubas.
" 19	3.595	71.90	Philippines, 3.58; Cubas, 3.58, 3.61.
" 22	3.52	70.40	Porto Ricos.
" 26	3.58	71.60	Philippines.
" 27	3.61	72.20	Porto Ricos, Philippines.
" 28	3.655	73.10	Porto Ricos, 3.67, 3.64; Cubas, 3.64.
" 31	3.64	72.80	Porto Ricos.
April 1	3.595	71.90	Porto Ricos, 3.58, 3.61; Cubas, 3.61.
" 2	3.625	72.50	Cubas, 3.61; Porto Ricos, 3.61, 3.64; Philippines, 3.61.
" 4	3.623	72.47	Porto Ricos, 3.61; Philippines, 3.61; Cubas, 3.64, 3.62.
" 5	3.52	70.40	Cubas, Porto Ricos.
" 7	3.49	69.80	Porto Ricos.
" 8	3.46	69.20	Cubas.
" 9	3.433	68.66	Cubas, 3.39, 3.45, 3.46.
" 15	3.42	68.40	Cubas.
" 24	3.405	68.10	Cubas, 3.39; Porto Ricos, 3.42.
" 26	3.39	67.80	Cubas.
" 29	3.33	66.60	Cubas.
May 1	3.30	66.00	Cubas.
" 6	3.27	65.40	Cubas, Philippines.
" 9	3.24	64.80	Cubas.
" 12	3.225	64.50	Cubas, 3.24, 3.21.
" 13	3.18	63.60	Philippines, 3.19, 3.17.
" 15	3.182	63.65	Philippines, 3.155; Cubas, 3.21.
" 16	3.24	64.80	Philippines.
" 19	3.21	64.20	Cubas, Philippines.
" 21	3.19	63.80	Cubas, 3.21; Porto Ricos, 3.17.
" 22	3.17	63.40	Porto Ricos.
" 23	3.14	62.80	Philippines.
" 24	3.425	68.50	Cubas, 3.39; Porto Ricos, 3.46.
" 27	3.132	62.65	Cubas, 3.14; Porto Ricos, 3.125.
" 29	3.14	62.80	Philippines.
June 4	3.225	64.50	Cubas, 3.21; Philippines, 3.21; Porto Ricos, 3.24.
" 5	3.24	64.80	Philippines, Porto Ricos, Cubas.
" 6	3.26	65.20	Porto Ricos, 3.27; Cubas, 3.27, 3.25; Philippines, 3.27.
" 10	3.255	65.10	Porto Ricos, 3.27; Cubas, 3.24.
" 11	3.27	65.40	Porto Ricos.
" 13	3.315	66.30	Cubas, 3.30, 3.33; Philippines, 3.33.

THE HAWAIIAN PLANTERS' RECORD

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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Chlorotic Streak Disease of Sugar Cane

A brief history and a description of chlorotic streak disease which occurs on several sugar cane varieties in Hawaii is presented. An account of the studies regarding its cause, an outline of investigations now being conducted and certain measures for its control are also offered.

Field studies have shown that the disease is readily transmitted with cane cuttings and this fact places the trouble in the category of systemic plant diseases. The effect of the disease on sugar yields will be determined in field tests by harvesting separate plots planted with diseased and healthy cuttings.

Nematodes Associated with Sugar Cane in Hawaii.

A brief resume of the nematode genera found in the cane fields of Hawaii, together with illustrations of some of the species.

Irrigation Measurements:

Greater accuracy in the measurement of irrigation water to small experimental plots may be had by using the Parshall Flume with six-inch throat. An arrangement by which the hook-gauge can be made portable for rapid transfer from one installation to another is described in this issue.

Twenty installations of this type at the Waipio Substation are proving satisfactory. Waimanalo Sugar Company has recently made fourteen similar installations for water measurements to level ditch plots.

A Practical Use of Cane Growth Measurements:

A comparison of the winter and summer growth of sugar cane at Kukuihaele is presented by W. C. Jennings, who makes this study by the aid of growth measurements.

Since the winter season is almost certain to be accompanied by a fair rainfall and the summer months are often subject to severe drought, it is important in that district to differentiate between the potential growth value of the different times of the year.

Cane Varieties in the Philippines:

The principal varieties in the Philippines are discussed together with some of the newer seedlings which are being tested against them.

Sugar Cane Breeding in the Philippines:

With improvements in field practices in the Philippines has come a desire for canes better able to respond to the improved conditions than the old Luzon White and Negros Purple. This has resulted in considerable interest in sugar cane breeding. A brief account is given of the past and present status of cane breeding work in the Philippines.

An Open Letter:

"An Open Letter to All Sugar Techonologists" from F. W. Zerban, general chairman of the International Society of Sugar Cane Techonologists, invites cooperation of authors of technical papers, requesting that abstracts of papers be submitted for publication in *Facts About Sugar*.

Rat Control in Hawaii:

An historical outline of pertinent work done here and elsewhere on rat control is followed by a report of the recent investigations conducted on the island of Kauai on the control of rats. Tests on 453 wild caged rats of various species are reported. Strychnine rat baits were found inefficient and distasteful to rats. Barium carbonate preparations, although highly toxic, were ignored until the rats, deprived of other food, were forced to eat them.

Thallium sulfate-treated wheat bait, of a 1 to 1,000 weight ratio, proved to be highly effective, was eaten by all rats offered such preparations and death ensued within an average of three days in all cases. Tests with field rats proved the effectiveness of this bait and it has since been adopted on those plantations which are now practicnig rat control in the cane fields. A marked reduction in numbers of rat-eaten canes coming to the mills has been effected within the first year of general use. Improved mill juices have resulted from the use of thallium sulfate-treated wheat baits.

The formula for preparation is detailed and the dangers involved in handling the drug are pointed out, as well as the precuations to be taken. The prepared rat bait is now manufactured and distributed by the Pacific Guano and Fertilizer Company, of Honolulu. The use of ready-prepared rat bait is to be preferred for

plantation use if facilities for the safe and economical preparation of thallium rat baits are lacking.

Periodic Harvesting Experiment—Waipio.

A study of the yield of cane given by the H 109 variety when planted at different periods of the year. Chemical analysis of millable cane, tops, trash and dead cane, at each period of harvest, have made possible a determination of the amounts of mineral nutrients removed from the field during the growth of the crop.

Hydrogen Ion Concentration:

A discussion of the theory involved in the use of the tenth normal calomel electrode employed in determining pH is presented from a purely chemical standpoint. The several effects of changes in temperature, pressure, and composition are treated, and equations included by which the magnitude of these effects may be calculated.

The Probable Error of Field Tests with Sugar Cane:

A statistical examination of the results of field experiments conducted by the agricultural department throughout the islands during the last ten years shows an average probable error of 6.6 per cent.

Considerable evidence is presented to show that this probable error has been influenced by the environmental variability that exists in the experimental areas. A distinct tendency toward a smaller error is noted with the higher tonnage yields, as well as on the plots which have had an ample supply of plant food nutrients, particularly nitrogen.

There is some indication that plots somewhat larger in size than those ordinarily used here, may carry a lower probable error.

Statistical Data for the Interpretation of Field Experiments:

A statistical analysis of a large amount of experimental data at Ewa Plantation Company has defined the characteristics of the normal curves of error to be expected in cane and sugar plot yields and in juices. Extreme deviations from the mean values were found to consistently lie beyond the limits of the normal curves of error concerned which prompted the development of a systematic method of plot elimination in the analysis of field experiments. Consideration has been given to the number of plot replications in their effect upon the significance of results.

Chlorotic Streak Disease of Sugar Cane

By J. P. Martin

The purpose of this article is to present briefly a history and a description of a peculiar leaf streaking disease occurring on several sugar cane varieties in Hawaii, an account of the studies to date regarding its cause, as well as an outline of investigations now being conducted and certain suggested measures for its control.

History

Raymond Conant, research agriculturist, Olaa Sugar Company, Limited, forwarded specimen material consisting of leaves of P.O.J. 36 to the Experiment Station in October, 1929. The leaves exhibited one or more long, irregular, yellowish, chlorotic streaks often extending the entire length of the leaves.

The chlorotic streaks were studied by members of the pathology department. Isolations made by C. C. Barnum from lesions on these leaves yielded several types of bacteria and fungi. Inoculations made with ten of the bacterial cultures failed to produce any symptoms similar to those occurring in the field. Histological examinations of the streaks by D. M. Weller, demonstrated that both xylem and phloem were affected and that the bundles in the advancing areas of the lesions were filled with a gum-like substance. The chlorophyll-bearing cells within the affected tissues were of a pale green or light yellowish color. Stained preparations showed bacteria (possibly of a secondary nature) to be present in the parenchyma cells surrounding the chlorophyll-bearing parenchyma and in the motor cells. A report of these investigations appears in the Experiment Station *Monthly Letter* for November, 1929.

During the month of October, 1929, inspections were made on several plantations on Hawaii to study the disease. The fields at Olaa Sugar Company were visited in company with Mr. Conant, who stated that the disease was first seen during the summer of 1927 on P.O.J. 36 plant cane and that it was again observed on the same variety of cane during the summer and fall of 1929.

A preliminary survey made by Royden Bryan and the writer, in October, 1929, showed that the disease was present on P.O.J. 36 at the following plantations: Hilo Sugar Company, Pepeekeo Sugar Company, Onomea Sugar Company, Honomu Sugar Company and Laupahoehoe Sugar Company. Other plantations on Hawaii were not visited at that time.

It was suggested to Mr. Conant during the course of this visit in October, 1929, that plantings of both diseased and healthy cuttings of P.O.J. 36 should be made in order to determine whether or not the disease is transmitted with cuttings. Mr. Conant installed an observational test to determine this point in a small plot near the mill. In addition, cuttings of P.O.J. 36 affected with the disease were selected from Field W of Olaa Sugar Company and taken to Honolulu and planted at the pathology plot, so that frequent observations could be made on the plants grown

from the diseased cuttings In three or four months, very definite lesions typical of the disease appeared on the shoots developing from the diseased cuttings planted at Olaa Sugar Company as well as on the shoots developing from the diseased cuttings planted at the pathology plot. In both of these observational tests, the plants grown from the healthy cuttings have developed no symptoms of the disease, even after ten months. It is significant that the healthy plants did not contract the disease even though they were in contact with the diseased plants The fact that the disease is readily transmitted by cane cuttings immediately places this disease in the category of systemic plant diseases.

A survey of the plantations on Oahu by Messrs Barnum and Carpenter, during the early part of November, 1929, revealed the fact that the yellowish lesions of the disease were present on P O.J. 36 at Waimanalo and one case was found on P.O.J 36 at Waipio substation Several cases were observed on P O.J 36 during August, 1930, at the Kailua substation.

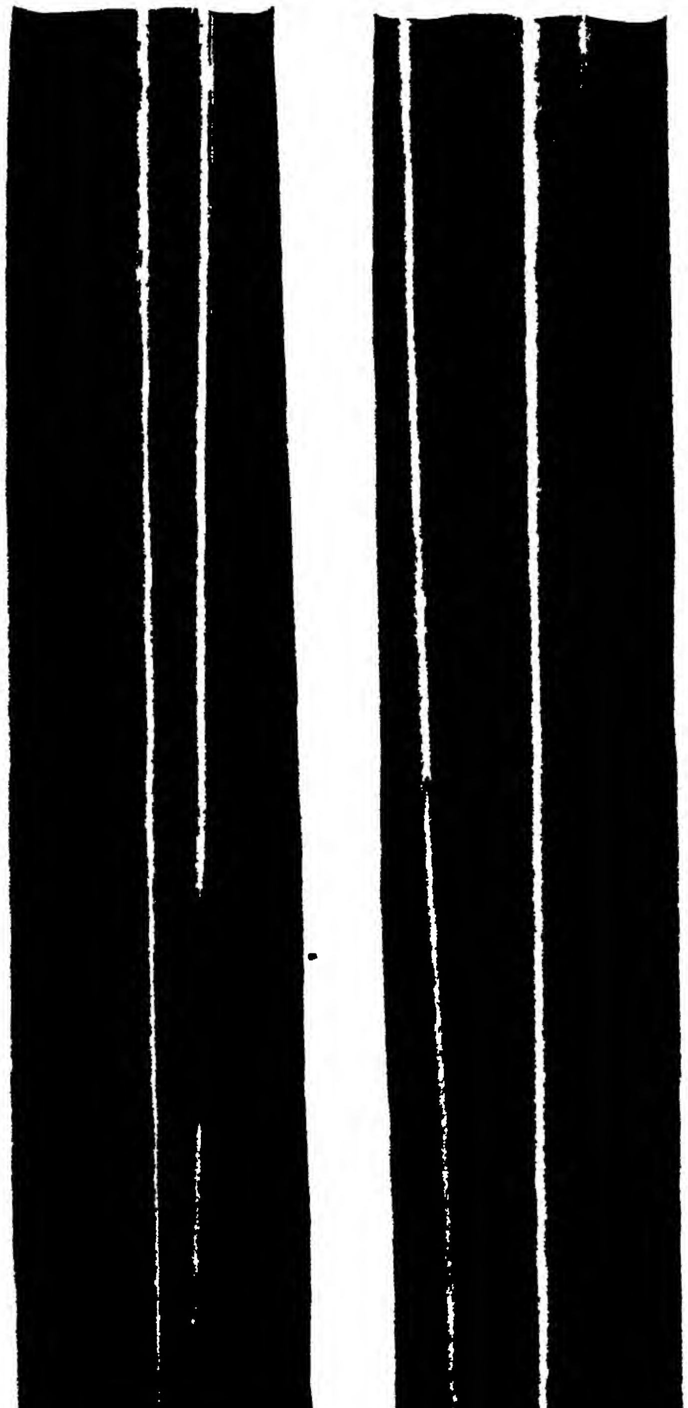
Since the disease was readily transmitted with cane cuttings, it became necessary to install further observational tests to determine its effect on sugar yields. Plots planted with diseased cuttings and others with healthy cuttings are to be harvested and the quantitative data secured are to be used in determining this point. At the present writing, observational tests are under way at Olaa Sugar Company, Hilo Sugar Company and the pathology plot, Honolulu.

In the *Monthly Letter* for February, 1930, it was stated that the peculiar yellowish streaks frequently observed on leaves of P.O.J. 36 and other varieties would in the future be referred to as symptoms of "chlorotic streak disease." To date, chlorotic streak disease has been observed on the following cane varieties: P. O J. 36, 36M, 234 and 979, U. D. 1, Yellow Caledonia, K 107, D 1135 and on a few of the newer varieties.

Description

The symptoms of chlorotic streak disease are easily recognized on the more mature leaves of an affected plant by the presence of long, irregular, yellowish, or chlorotic streaks. The streaks vary from 1/8 to 3/8 of an inch in width and in length from a fraction of an inch to the entire length of the leaf. The lesions on the leaves are somewhat irregular and wavy in outline as compared with the very definite stripes that are typical of red stripe disease. Also, the appearance of the lesions of chlorotic streak disease differs from the markings characteristic of leaf variegation in that the markings of the latter are well defined, have very sharp margins between the healthy and chlorotic areas, and usually extend onto the leaf sheath and occasionally onto the cane stalk. So far, lesions of chlorotic streak disease have not been observed on the leaf sheaths or cane stalks. The streaks are more or less parallel to the vascular bundles or veins of the leaves and, in the advanced stages, are quite conspicuous in contrast with the normal green color of the healthy portion of the leaves.

In the older streaks necrotic areas of an ash color are often present, which are separated from the healthy areas by a reddish-brown line. These necrotic areas correspond in shape to those of the large lesions and vary in length from a few inches to the entire length of the mature lesion.



Chlorotic Streak Disease
(On P. O. J. 36)

The earliest symptoms of the disease are manifested by the appearance of very indefinite yellowish streaks on the young leaves. These may occur on any portion of the leaf blade extending both upwards and downwards from the point of origin with an irregular outline, and follow the course of the vascular bundles. When one cane leaf is found affected with chlorotic streak disease it is not uncommon to find typical lesions on six or seven other leaves of the same stalk.

The leaf symptoms of chlorotic streak disease, as described above, are shown in the colored plate accompanying this article. Since the streaks are so definite on the more mature leaves, only such material should be used for positive diagnostic symptoms.

Many stalks exhibiting leaf symptoms have been cut open and examined. In a few cases a slight reddening of the vascular bundles, particularly at the nodes, has been observed. The red discoloration in the stalks has not as yet been proved to be a symptom associated with the disease. Further studies of this condition in the affected stalks are being made.

A cane disease manifesting symptoms similar to those of chlorotic streak occurs in Java and is known as The Fourth Disease; this terminology is used signifying that the trouble is the fourth vascular disease of sugar cane plants, the other three vascular diseases being Sereh, leaf-scald and gumming.

Studies of The Fourth Disease, in Java, have not disclosed an organism associated with the trouble and the cause of the disease is to date unknown. The Fourth Disease was pointed out to the writer in Java, in 1929, by Dr. G. Wilbrink, Directress of the Cheribon Sub-Experiment Station, on the cane variety P.O.J. 2878. Only an occasional diseased plant was observed and the disease was considered of minor significance.

While Dr. P. C. Bolle, pathologist of the Sugar Experiment Station, Java, was visiting the Hawaiian Islands in February, 1930, plants affected with chlorotic streak disease were called to her attention and she diagnosed the disease as The Fourth Disease.

Control Measure

As already mentioned, the disease is readily transmitted with cane cuttings and where a variety, such as P.O.J. 36, is being rapidly extended and is affected with chlorotic streak disease it seems highly advisable to recommend that only healthy cuttings be selected for planting material. To date, no serious losses have resulted but to prevent the spread of the disease and possible losses, should the disease prove to be serious, the plantations on which the disease now occurs would be justified in adopting this recommendation.

Discussion

In dealing with new sugar cane varieties we are continually confronted with new diseases in plant pathology by their appearance in the form of peculiar blemishes, markings, malformations, etc., which, in the past, have not been recorded. However, these diseases may have existed in the Territory in an inconspicuous or latent condition on the standard varieties and are only recognized on newer varieties due to the susceptibility of the latter to such maladies. Again, environ-

mental conditions may change and become extremely favorable for the development of certain cane diseases which, in the past, have been obscure or unknown.

The question naturally arises as to whether chlorotic streak disease was imported in recent years from Java through cuttings introduced from Washington, D. C.

If a systemic disease should be introduced in the cuttings of a new variety, it must be recalled that the introduced material is confined to a very small number of cuttings and that when a variety so introduced is expanded to many acres, we should expect a very large percentage of the cane so propagated to show a high degree of infection. With the disease under discussion this, however, is not the case. We find symptoms of the chlorotic streak disease in a very small percentage of any one variety that shows the disease.

This leads us to believe that the malady has been harbored in one or more of our standard varieties in an obscure form and that it now manifests itself on the more susceptible canes.

Summary

A chlorotic leaf streak now known as chlorotic streak disease, which occurs on several sugar cane varieties in Hawaii, was first called to our attention in October, 1929. According to present records, this disease has been observed but a short time in the Territory.

Laboratory studies have not established the cause of the disease. Field studies have shown that the disease is readily transmitted with cane cuttings, which fact places the disease in the category of systemic plant diseases.

The effect of the disease on sugar yields is being determined by harvesting separate plots planted with diseased and healthy cuttings.

The disease is recognized by the presence of one or more irregular, yellowish, or chlorotic streaks, especially on the older leaves. The lesions on the young leaves are somewhat indefinite. The margins of the streaks are irregular or wavy in outline as compared with the very definite outlines of the stripes characteristic of red stripe disease and leaf variegation. Frequently, the lesions may occur on from one to seven or more leaves of an individual stalk.

The leaf symptoms of chlorotic streak disease are similar to those of The Fourth Disease which occurs in Java.

Since the disease is readily transmitted with cane cuttings, it has been recommended that when a variety is being rapidly extended and is affected with chlorotic streak disease only healthy cuttings should be used for planting material.

Acknowledgment

Both Raymond Conant, research agriculturist, Olaa Sugar Company, Limited, and Royden Bryan, assistant agriculturist, Experiment Station, H. S. P. A., have aided greatly with the field studies pertaining to chlorotic streak disease and their cooperation is greatly appreciated.

Nematodes Associated with Sugar Cane in Hawaii

By Gertrude Cassidy

While a few specialists have for some time recognized the role played by nematodes in agriculture, the vast number of agriculturists have only recently become aware of the extent of their range and their economic importance.

The definitely destructive work of a few species in special crops, such as the two species of Heterodera and a few species of Tylenchus, has been observed for many years and numerous remedies suggested for their control, yet the important part played by free-living nematodes both directly and indirectly, and the fact that the damage caused by nema pests is still increasing, is only now being fully recognized.

Nematode investigations have been intermittently in progress in the Hawaiian Islands since 1905. At that time much valuable work was contributed by Dr. N. A. Cobb, who made numerous examinations of cane roots on the islands of Hawaii, Maui and Kauai, and identified the following eleven nematode genera:

1. Dorylaimus
2. Tylenchus
3. Mononchus
4. Prismatolaimus
5. Plectus
6. Monhystera
7. Anthonema
8. Diplogaster
9. Cephalobus
10. Rhabditis
11. Heterodera

To this generic list of nematodes associated with sugar cane in Hawaii may now be added the following seventeen genera:

1. Axonchium (1)
2. Criconema (1)
3. Xiphinema (1)
4. Aphelenchus (2)
5. Discolaimus (2)
6. Isonchus (2)
7. Actinolaimus—Not previously recorded
8. Acrobeles "
9. Bunonema "
10. Cyatholaimus "
11. Chromadora "
12. Dolichodorus "
13. Iota "

14. Ironus—Not previously recorded.
15. Rhabdolaimus "
16. Triplya "
17. Tylopharynx "

Of this additional group more than half are spear-bearing nematodes known to be plant feeders which obtain their nourishment through punctures in the root surface made by the sharp protrusile spear with which each is armed.

The importance of this exoparasitic group in Hawaii has been somewhat neglected of late, owing to the extensive plantation survey which was recently completed.

No attempt was made in this survey to include the exoparasitic forms (i.e., those which feed from the outer surface of the plant as contrasted with those which not only obtain nourishment from the plant but actually inhabit the internal root structures besides), as the vastness of their numbers precluded investigation over so great an area. (All plantations of Oahu, Maui, Kauai and Hawaii were included in the nematode survey.)

The importance of these exoparasitic forms has not, however, been forgotten and the work of identification is at present in progress.

The economic importance of these exoparasitic nematodes has long been recognized, though little or no mention has been made hitherto in these pages. The following extract gives a general indication of the importance of this group from the viewpoint of the agriculturist (3):

In recent years the study of free-living nemas has been greatly increased, and as a result the problems connected with nema pests have acquired a new aspect. . . . Today we know that soil nematodes play a very important role.

1. As consumers and destroyers of our crops—often destroying whole fields, but much oftener decreasing their yield in a less perceptible degree.

2. As consumers of, and as important workers in the distribution of the bacterial flora of the soil. Their activity is certainly not restricted to denitrifying bacteria, but extends to nitrifying forms as well. A closer study may show relations of very great importance. They carry bacteria and fungus spores everywhere. Wounds on roots or other parts of plants may very often be infected by bacterial and fungous diseases carried by these nematodes.

3. As having relationships with fungi upon which some species are known to feed. According to Zopf fungi on the other hand may use nematodes as prey.

4. As consumers of protozoa. It is known that certain fresh-water nemas feed specially on protozoa, sometimes apparently on a single species. There is a probability that some soil species may feed in a similar way, and further investigations may enable us to combat plant-injurious protozoa by the use of these nemas.

5. As furnishing a control for plant-injurious nemas. This refers to the work of predatory nemas, such as *Mononchus papillatus*, whose feeding habits have been described in this paper. There are other species of nemas with a similar significance. Here is a great field for study. Investigations should also be carried on to show more definitely the relations of these predatory forms to rotifers, oligochaetes and other soil animals.

6. As a factor in the humification of the soil, in transformation and removal of all kinds of organic matter, decaying bodies, etc.

7. As assisting in the aeration of the soil. We know how very important aeration of soil is for the growth of bacteria and all kinds of plants. Quite possibly these millions of nematodes living in the soil are highly useful aerators.

In order to solve the problem of the relation of the soil nemas to soil fertility, we require a knowledge of the nema population in the soil itself and we also need to know:

1. The composition of the nema population, the species found and their numeric representation in all kinds of soil—sandy, humus, swampy, dry-soil, hard clay, etc.
2. The horizontal and vertical distribution of nemas in all kinds of soil and the reasons for this.
3. The seasonal changes of the different species, the number of species and the number of individuals of each species.
4. The influence of habitat on the nematode population including physical, chemical and biological factors found in the habitat. The biological factors include kinds of crops and other forms of vegetation that may be present.

The working out of these problems will surely enable us to conclude why nema pests are absent in some cases, and why in apparently similar conditions they exist in such enormous numbers. A large field is thus opened up for investigations, the results of which will be of great importance to agricultural science.

Mononchus Bast. 1866, the Predacious Nematode—

Specimens of this genus were first identified around cane roots in Hawaii by Dr. N. A. Cobb, 1905.

At that time these nemas were accepted with the other ten genera as definitely established plant parasitic forms. This viewpoint has been completely reconsidered in the light of recent investigation and Mononchus is now regarded hopefully by reason of its predacious habit, as a probable means of nematode control, and an ally in the warfare waged upon all plant destructive forms.

The following extract gives an adequate and brief summary of the situation (4):

No free-living nematodes have gained more interest during recent years than those constituting the genus Mononchus; this is because the latest discoveries have led to a complete change of view concerning their economic relationships. Careful examination, here recorded, of a large number of specimens belonging to many different species of Mononchus, has fully demonstrated the predaceous character of certain common and widely spread soil-inhabiting species—which are found to feed on other small animal organisms, such as protozoa and rotifers, and, most interesting of all, on other nemas.

Economic Importance—If, as is often the case, the nemas destroyed by the mononchs are nemas injurious to agriculture then the mononchs are beneficial to man. The first definite instance of this was reported in the *Journal of Agricultural Research* in September, 1914: *Mononchus papillatus* was shown to feed upon *Tylenchus semipenetrans*, the latter a nema infesting the roots of citrus trees. Since that time the writer has observed many similar instances, fourteen of which are recorded herein.

Formerly mononchs were considered harmful to vegetation. The basis of this opinion was twofold: First, they were known to congregate about the roots and between the leafsheaths of plants, especially succulent plants, in sufficient number to justify the opinion that they would be harmful, provided they were vegetarians. Second, vegetable matter was often found in their intestines.*

More careful investigation, however, has disclosed other facts incompatible with this opinion that mononchs are harmful to vegetation. The food-habits of mononchs have now been more carefully investigated as herein recorded, and each species so studied has proved to be carnivorous. . . .

* (Found to be due to the Mononchus sp. having devoured a parasitic prey whose intestinal contents previously contained vegetable debris.—G. C.—Author.)

As we gain familiarity with the food habits of nemas, it becomes possible on this new basis to make comparative anatomical studies, the results of which may be applied in determining the food habits of newly discovered genera and species. . . .

. . . . Picture these ferocious little mononchs engaged in a ruthless chase in the midst of stygian darkness. We may imagine them taking up the scent of the various small animals upon which they feed, among which almost anything they can lay mouth to seems not to come amiss, and pursuing them with a relentless zeal that knows no limit but repletion.

How many acres have their organic balance determined by their millions of prowling mononchs? . . .

Method of Attack—When used in conjunction with the strong dorsal tooth and the powerful lips, the rasps are remarkably efficient organs. The mononch glides up to its quarry and makes its onslaught by a quick snap of the head, throwing its jaws suddenly wide open and grappling its prey by means of the inner armature of the lips. As the jaws close in, the victim's body is jammed against the point of the dorsal tooth, as well as against the rasps and in this way is at once both punctured by the tooth and lacerated or milled by the rasps. . . .

Fig. 1. A mononch about to seize its victim. (After Cobb.)

Geographic Distribution—Variety of Habitat—Mononchs are found in all the habitable regions of the world. They inhabit the soils and fresh waters of every clime, occurring even at great depths in lakes and at very high altitudes on mountains. While we have only just begun to learn the details of their geographic distribution, it is already manifest that some species are cosmopolitan. . . . *Mononchus longicaudatus*, for instance, is known from the tropics, from temperate regions and from very cold regions and inhabit both soil and fresh

water. Another species, *Mononchus brachyurus* is known from warm springs and from cold Alpine lakes.

Both of the two species cited (*M. longicaudatus* and *M. brachyurus*) together with several other species are readily found associated with sugar cane in Hawaii. Recent experimental work has gone to prove the unquestionable value of members of this genus in reducing the population of plant injurious forms. *Mononchus papillatus* (also present in Hawaii) has been observed to devour as many as eighty-three Heterodera in one day, and it has been definitely proved that members of this genus are not vegetarians and are therefore beneficial to the welfare of the crop and industry.

Considerable discussion has been stimulated during the recent investigations as to the exact amount of damage which can be attributed to nematodes infesting cane. With a view to demonstrating this to the satisfaction of outside workers, the accompanying chart was made to demonstrate the numerical infestation of cane root per linear centimeter of root. The stool selected was one of hundreds examined in the course of the nematode survey. This stool was listed under the heading of "Moderate Infestation with *Tylenchus similis*" (a standardization determined by an estimated 50 per cent root infestation). One linear centimeter of infested root was found to contain 600 worm forms (*Tylenchus similis*) and 300 eggs (*Tylenchus similis*).

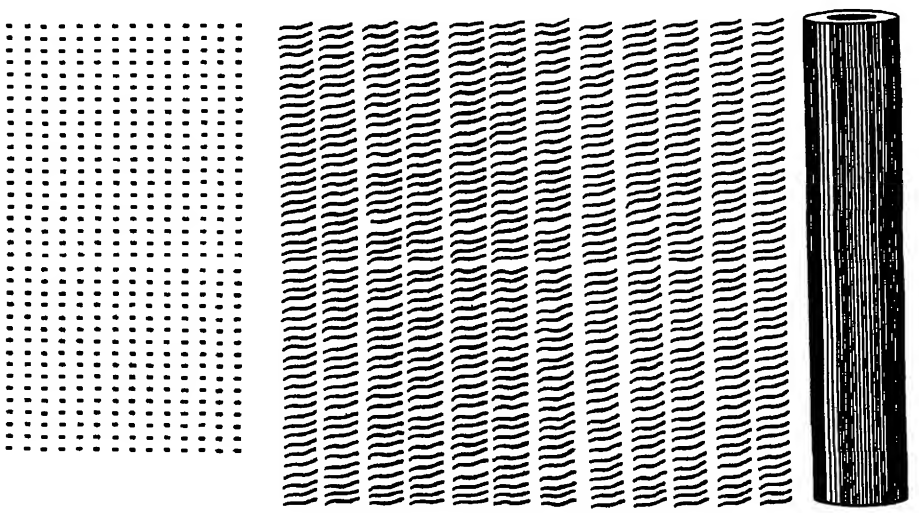


Fig. 2. A representation of the actual count of nematodes and eggs (*Tylenchus similis*) found in 1 cm. of infested cane root (Hawaii, 1930). x 6.4.

The diagrammatic representation presents the root and the infesting nematodes in their correct proportions. Further comment is perhaps unnecessary as the individual may judge for himself the probable proportions of a severe infestation. Extensive collections of exoparasitic cane nematodes have been made during the past few months and much valuable material prepared for identification.

To reiterate the difficulties attendant upon this branch of the work is unneces-

sary as allusion to it may be found in practically every paper ever published in connection with the subject.

Valuable information generously imparted by other workers in the United States and in Europe as to additional equipment and elaborated technique has facilitated the work appreciably and already a certain amount of identifications have been completed. The recent collections prove the soils of our cane fields to possess a large and varied population of nematode genera. The majority of these have not previously been recorded for Hawaii and include many new and little known species.

Tylopharynx annulatus Cassidy (in. litt.). A new species of a genus not hitherto recognized in Hawaii. This nematode is possessed of a strong, highly chitinized tripartite spear and was found very abundantly around the roots of sugar cane growing upon land previously in rice. In many ways it resembles the endoparasitic *Tylenchus similis* but as yet this genus (*Tylopharynx*) has not been observed within the internal root structures of the cane. (See Fig. 3.)

Tylenchus spiralis Cassidy (in. litt.). A new species closely resembling *Tylenchus dihystera* Cobb commonly found associated with the roots of sugar cane, pineapple, banana, rice and coffee in Hawaii. This species is distributed throughout the islands and is apparently uninfluenced by altitude or by varied soil environment. It has been found in sandy soils at sea level, in the colloidal soils of rice lands and in forest soils rich in humus at an elevation of more than 1000 feet. (See Fig. 4.)

Actinolaimus elaboratus (Cobb) Cassidy (in litt.). An unusually large sized species, originally found by Cobb, associated with diseased cane in Kohala and described by him in 1905 under the genus Dorylaimus. No diagrammatic representation of this species has previously been published. The highly complex pharyngeal cavity containing the strongly chitinized protrusile spear is worthy of attention. *Actinolaimus elaboratus* is an exoparasite believed to puncture the root surface and so obtain nourishment by extracting the root juices by means of its powerful hollow spear. (See Fig. 5.)

This genus is found in Hawaii commonly associated with the roots of sugar cane and of coffee. It has been demonstrated at high elevations (over 1000 feet) and also in lowland areas near sea level in various types of soil.

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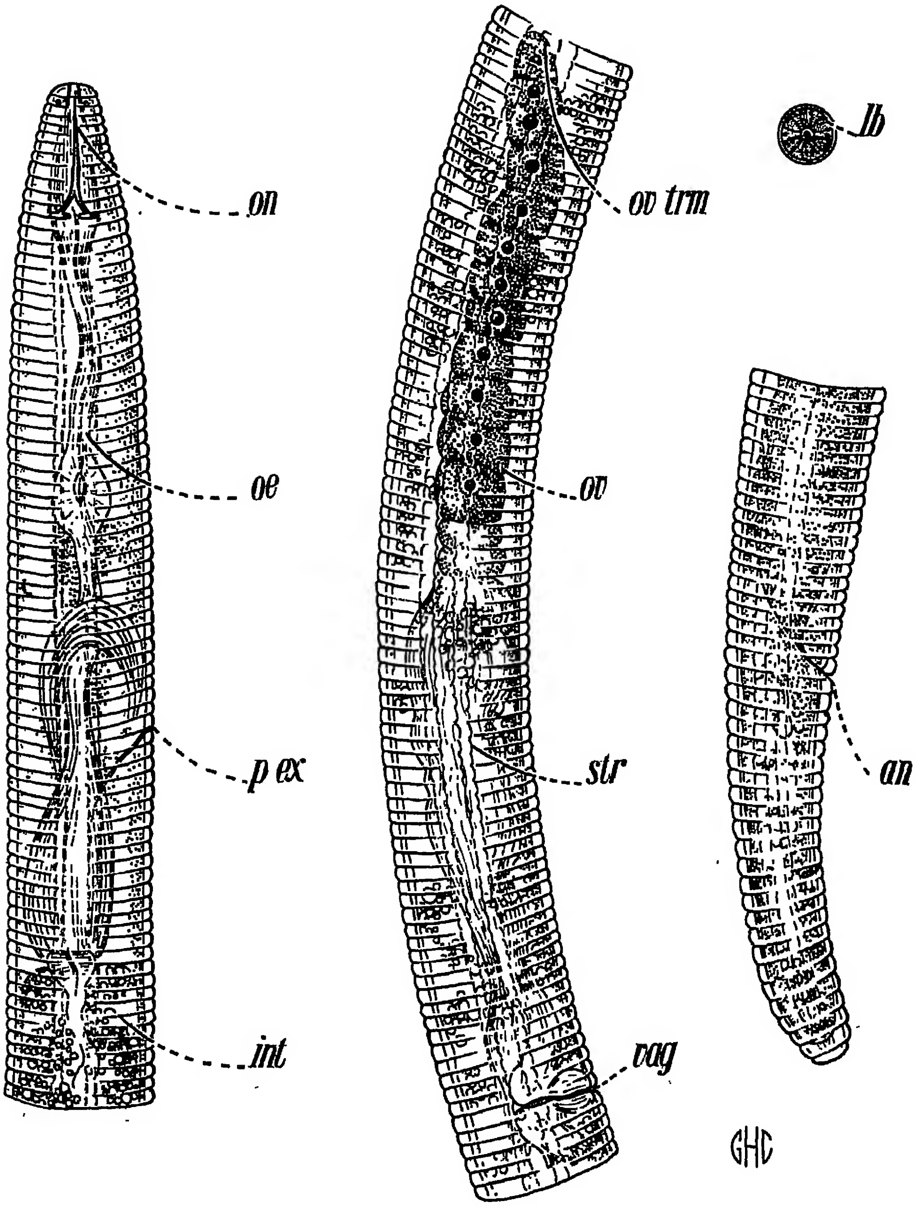


Fig. 3. *Tylopharynx annulatus* x 814.

Adult female measuring .65 mm. (body sections and front view of head).

an—anus; *int*—intestine; *lb*—lip; *oe*—oesophagus; *on*—spear; *ov*—ovary; *ov trm*—termination of ovarian tube; *p ex*—excretory pore; *str*—longitudinal striations; *vag*—vagina.

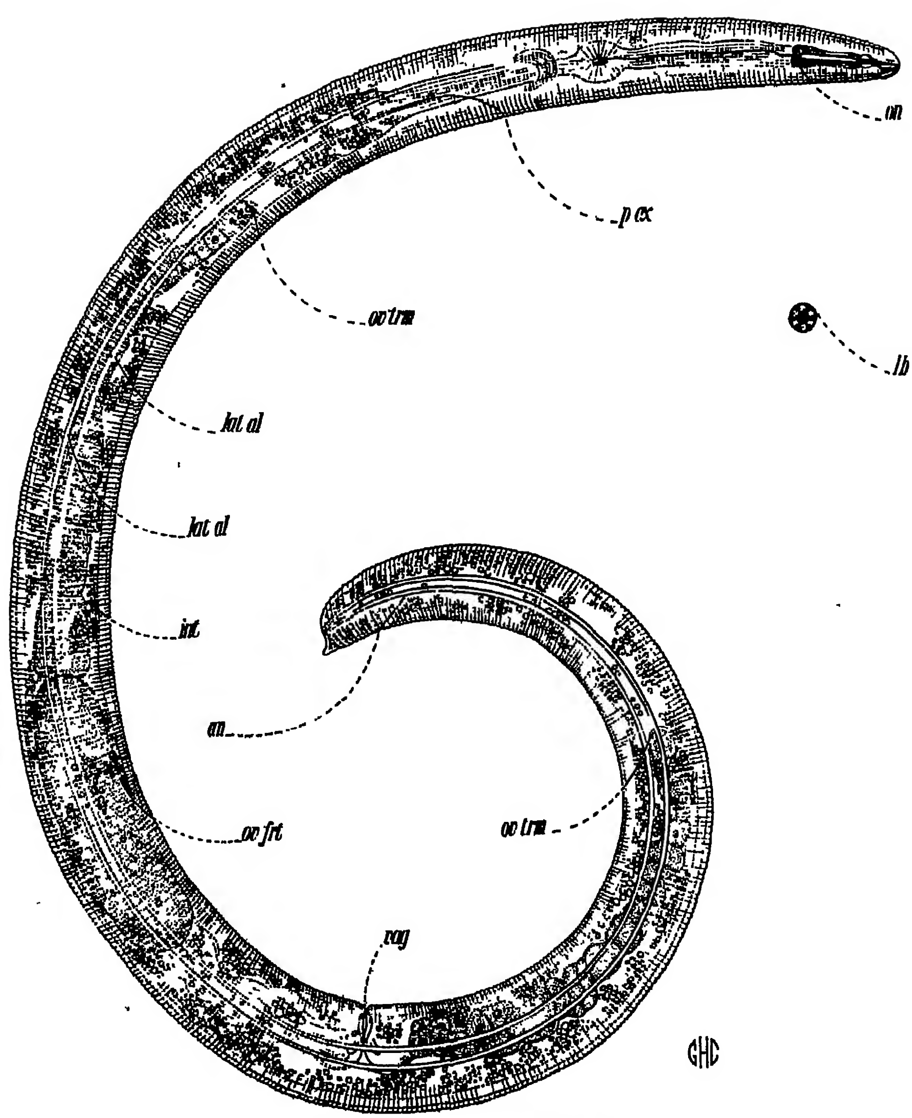


Fig. 4. *Tylenchus spiralis* x 470

Adult female measuring .65 mm. Inset—front view of head.

an—anus; *int*—intestine; *lat al*—lateral ala; *lb*—lip; *p ex*—excretory pore; *on*—spear; *ov frt*—fertilized egg; *ov trm*—termination of the ovary; *vag*—vagina.

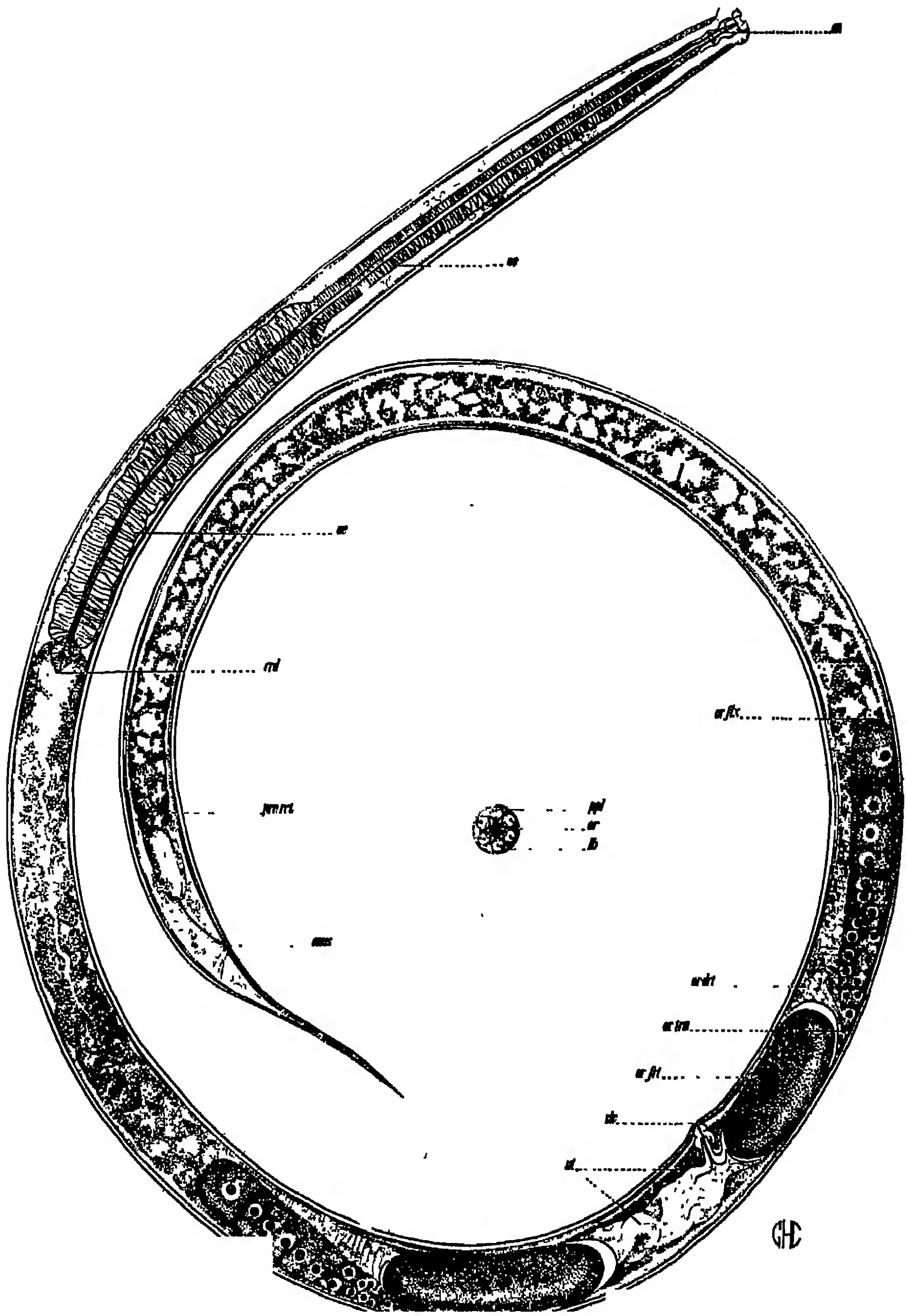


Fig. 5. *Actinolaimus elaboratus* (Cobb) x 284.

Adult female measuring 1.7 mm. The central figure represents the front view of the head.

anus—anus; *crd*—cardia; *lb*—lip; *oe*—oesophagus; *on*—spear; *or*—mouth; *ov dct*—oviduct; *ov flx*—ovarian flexure; *ov frt*—fertilized egg; *ov trm*—termination of ovarian tube; *ppl*—papilla; *pre rct*—pre-rectum; *ut*—uterus; *vlv*—vulva.

Measurement of Irrigation Water to Small Plots at the Waipio Substation

By H. R Shaw

Detailed studies of certain relationships of irrigation water to the cane plant have been in progress for several years at the Waipio Substation. Due to the limited area available for irrigation investigations and to the advisability of lessening errors caused by soil variation, unequal water distribution, and seepage losses in level ditches, attempts have been made to measure the water at the junction of the level ditch and watercourse Plots to which irrigation water is measured vary in size from 0.1 to 0.2 acre.

Difficulties have been encountered in perfecting a type of measuring device which would be satisfactory under such conditions. Portable steel weirs set in the level ditch were abandoned because of the seepage of water around the facings and because of the difficulty in setting the weir plumb and vertical in the level ditch. Concrete installations of submerged orifices used with Great Western meters have also proved rather unsatisfactory. Inherent disadvantages of the sub-

Six-inch Parshall Flume with hook gauge in place.

merged orifice as a type of control and of the Great Western meter as a type of recorder were augmented by frequent clogging of the orifice and meter propeller with trash and algae.

As the basic results of the experiments are dependent on the accuracy of the water measurement, it was necessary to devise a type of measurement which would be as accurate as possible without disproportionate costs in labor and material

The Parshall (Venturi) Measuring Flume, constructed according to specifications given in Bulletin 336 of the Colorado Experiment Station, was adopted as the most accurate and satisfactory means of water measurement. A steel form was constructed by means of which concrete Parshall installations with 6-inch throats could be made The crest of the flume was set 6 inches above the level of the watercourse directly below the proposed installation in order to insure free flow discharge The structural strength of the flume is provided by a backfill of

Hook gauge mount and carrier.

field stone The concrete (1:3:6 mix of cement, beach sand, and rock sand) serves as a mortar and as a smooth facing of the flume sides. The total cost of the flume in place is estimated at approximately $10.

The actual measurement of water is made by means of a hook gauge which can be moved from one installation to another. A stilling well, 8 inches in diameter, is cast at the same time that the walls of the flume are set. The bottom of

the stilling well is 6 inches below the level of the flume floor so that silting space is provided. A one-half inch pipe leads from the flume wall, at a point two-thirds of the distance from the crest to the entrance and just above the floor level, to the stilling well. An upright, 4" x 4" x 24" is set vertically in the face of the stilling well wall. In the upright, a 2" x 2" groove is cut with the base of the groove level with the floor of the flume. The hook gauge is mounted on a 4" x 4" x 24" which is cut to 2" x 2" about 6 inches from the top. The 2" x 2" portion of the hook gauge mount slides into the groove on the carrier, the upper portion of the mount resting firmly on the top of the carrier, and the tip of the hook on a level with the carrier base. The gauge may be checked readily and frequently with a level by reading the rod when placed on the floor of the flume,

Reading hook gauge in place.

then resting the rod lightly on the tip of the hook when the gauge vernier is at zero. The gauge screw is adjusted until the rod reading is the same as when on the flume floor. The correction may then be read directly from the gauge vernier.

It is necessary, of course, to have an operator of the hook gauge constantly present during the irrigation. Under present conditions at Waipio, from one to two minutes is required for the irrigator to complete each line. There is comparatively little fluctuation in head after irrigation to the plot has started. The gauge operator determines the head over the flume every minute by adjusting the

gauge screw until the tip of the hook makes a "pimple" on the water of the stilling pond, and then reading the head directly from the vernier. He also records the time required by the irrigator to fill the furrow with water. If more than one minute is required to fill the furrow, the average discharge is taken from a series of readings at one-minute intervals. The figures are recorded in the table shown below, and the discharge in cubic feet for each line is determined from prepared tables showing the relation of head to discharge, and of discharge and time to total amount. The sum of cubic feet per line for the entire plot can be easily converted to an application figure of Gallons or Acre Inches per Acre.

This method of water measurement to small plots probably requires too much detail and attention to be employed in the average plantation experimentation. Where the success of the experiment depends upon the accuracy of water measurement, however, it is felt that this method will give greater satisfaction than any so far developed.

WAIPIO SUBSTATION
Irrigation Data
Parshall Flume Measurement

Experiment F — Date.......... ....
Plot No. 6 — Irrigator...... ....
Time Started: 6:04
Time Finished: ....

Hour	Min.	Sec.	C.F.S.	Head	Cu. Ft.
6:04	1	60	.20	.23	12.00
6:05	2	120	.20	.23	27.60
6:07	1	60	.22	.24	14.44
6:08	2	120	.22	.24	28.80
6:10	2	120	.22	.24	28.80
6:12	1	60	.23	.25	15.00
6:13	2	120	.23	.25	30.00
6:15					

Winter Growth at Kukuihaele

By W. C. Jennings

This is the first of a series of papers dealing with cane growth studies conducted on the Kukuihaele division of Honokaa Sugar Company during the past five years.

This paper is concerned principally with emphasizing the large percentage of our total growth which is secured during the winter months. Climatic conditions and the elevations at which cane is grown at Kukuihaele are similar, in a large degree, to most of Hamakua and also the Kohala district. Later papers will deal with data collected during 1923 and 1924 in the Kohala district, which support this supposition that conditions are similar.

The average monthly cane growth at Kukuihaele from November 1, 1924, to July 31, 1930, is tabulated below. These averages are the result of from 800 to 1400 measurements taken monthly at from 150 to 1650 feet elevation and at all times as nearly as possible evenly divided between young cane, or first season growth, and cane which is making second season growth.

TABLE I

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1924											5.13	3.81
1925	2.81	3.90	4.41	5.49	7.21	6.51	7.83	7.22	9.71	7.06	5.34	2.67
1926	2.54	3.34	5.23	6.08	6.85	5.89	4.91	7.93	8.75	7.80	8.82	3.92
1927	2.73	3.03	3.56	8.27	5.53	5.07	7.32	8.77	7.71	7.62	5.92	4.65
1928	3.43	2.89	3.83	6.78	8.37	6.94	9.35	8.55	8.40	4.35	5.26	3.53
1929	4.05	5.13	5.19	7.89	9.53	4.58	5.08	6.92	3.99	2.43	5.17	3.52
1930	4.61	6.56	6.34	6.82	5.38	7.91	6.25					

Table II gives the monthly rainfall averages over the same period.

TABLE II

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1924											7.79	.72
1925	7.23	1.18	9.44	6.60	3.61	2.52	1.50	7.82	2.15	2.13	3.43	.46
1926	1.21	2.66	1.41	8.31	1.53	4.69	2.29	5.01	2.69	5.74	5.23	1.99
1927	10.62	2.28	2.10	11.43	.86	1.08	6.99	3.20	3.78	2.33	8.14	7.93
1928	3.73	3.05	3.78	1.75	4.57	2.00	5.83	2.51	4.29	1.82	6.56	7.79
1929	12.03	14.98	10.31	8.29	2.75	1.13	2.50	6.27	.34	.48	13.65	17.54
1930	6.50	7.20	7.79	16.93	4.14	6.08	3.94					

For a number of years W. P. Naquin, for the purpose of comparing the annual winter and summer rainfall, has been terming the period from November 1 to April 30, winter, and May 1 to October 30, summer. This segregation of the months has been used in compiling the following data:

The data contained in Tables I and II are expressed graphically in Figs. 1, 2 and 3. In these three graphs the solid line is the growth curve, while rainfall is shown by the stepped or upright lines and all values are expressed in inches.

These data are complicated somewhat by the measurements taken on 250 acres of plant Uba during 1927 and 1928. This Uba was planted on hilltops that had been thrown out of cultivation several years before as having too poor soil for growing cane. Uba, which is slow growing at best as plant cane, under these conditions made very slow growth and somewhat depressed the curve for the years 1927 and 1928. The 1929 depression is due to the dry summer of 1929, which is brought out very clearly in Fig. 3.

To show in more detail the relation between rainfall and cane growth, Tables III and IV follow. Table III gives the rainfall for the years 1924 to 1929 with the five-year average for each month in inches and also the average percentage values for each month. Table IV gives the cane growth for the same period and the average monthly values in inches and percentage.

TABLE III

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1925	7.23	1.18	9.44	6.60	3.61	2.52	1.50	7.82	2.15	2.13	3.42	.46
1926	1.21	2.66	1.41	8.31	1.53	4.69	2.29	5.01	2.09	5.74	5.23	1.99
1927	10.62	2.28	2.10	11.43	.86	1.08	6.99	3.20	3.78	2.33	8.14	7.93
1928	3.73	3.05	3.78	1.75	4.57	2.00	5.83	2.51	4.29	1.33	6.56	7.79
1929	12.03	14.98	10.31	8.29	2.75	1.13	2.50	6.27	.34	.48	13.65	17.54
Total	34.82	24.15	27.04	36.38	13.32	11.42	19.11	24.81	13.25	12.09	37.00	35.71
Average	6.96	4.83	5.41	7.27	2.66	2.28	3.82	4.96	2.65	2.40	7.40	7.14
% value	12.04	8.36	9.41	12.58	4.60	3.95	6.61	8.58	4.58	4.15	12.79	12.35

TABLE IV

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1925	2.81	3.90	4.41	5.49	7.21	6.51	7.83	7.22	9.71	7.06	5.34	2.67
1926	2.54	3.34	5.23	6.08	6.85	5.89	4.91	7.93	8.75	7.80	8.82	3.92
1927	2.73	3.03	3.56	8.27	5.53	5.07	7.32	8.77	7.71	7.62	5.92	4.65
1928	3.43	2.89	3.83	6.78	8.37	6.94	9.35	8.55	8.40	4.35	5.26	3.53
1929	4.05	5.13	5.19	7.89	9.53	4.58	5.02	6.92	3.99	2.43	5.17	3.52
Total	15.56	18.29	22.22	34.51	37.49	28.99	34.43	39.39	38.56	29.26	30.51	18.29
Average	3.11	3.66	4.44	6.90	7.49	5.80	6.89	7.88	7.71	5.85	6.10	3.66
% value	4.49	5.26	6.38	9.93	10.78	8.35	9.9	11.34	11.10	8.42	8.78	5.27

Fig. 6 shows how closely the monthly averages for the past five years check with the averages of the past twenty-four years. This figure also shows that the months of June, July, September and October are consistently dry and that we can be fairly certain of getting good rains during August.

These tables and graphs show roughly what every plantation knows—that there is but little relation between winter rainfall and cane growth and a positive correlation between the amount of summer rainfall and cane growth. However, this paper is not primarily concerned with the factors controlling cane growth, else temperature and wind velocity data would also be included. These data have been arranged in this manner with the idea of drawing attention to the large percentage of our total cane growth which is secured during the winter months.

These figures support our belief that it is possible to increase our winter cane growth and that the greater part of any future increase in yields must come through agriculture that is based on the theory that every advantage must be taken of winter rains.

Field men in the Hamakua and Kohala districts are particularly apt to minimize the value of March and April as growing months. Cane that has lost color, in December and January has often started up rapid growth in March and April which at times is not visually evident until June or later. On the other hand, cane that has a good green color in June or July may have already slowed up the rate of growth due to lack of moisture. Color and general appearance alone are of no immediate value in determining the condition and rate of growth or the growth value of a given period. In the Hamakua district where cane growth is comparatively slow under average climatic conditions, the dependence on color or general appearance as a criterion of the condition of a field is apt to leave one at all times from four to ten weeks behind what is actually occurring. Our growth measurements show conclusively that by depending on visual evidence alone we would, most of the time, be several weeks late in determining what the rate of growth has been.

The management of this plantation believes that taking advantage of winter growth conditions has been a large factor in the constant gains in yield per acre which have been secured here over the period which these data cover. This has been done by planning crop rotation, fertilization and all agricultural practices to take advantage of the almost certain optimum moisture conditions of the greater part of the winter months. Temperature is, of course, the controlling factor during the winter months, but it is a comparatively constant or stable factor, while rainfall, which controls the amount of summer growth, is so uncertain a factor that we cannot hope to carry any crop through the summer months without one or more setbacks from lack of moisture.

Table V and Fig. 7 give the percentage of summer and winter growth for the years 1925 to 1929.

TABLE V

Year	Total Growth	Winter		Summer	
		Inches	%	Inches	%
1925	70.4	25.55	35.9	44.95	64.1
1926	67.33	25.20	37.5	42.13	62.5
1827	72.35	30.33	41.9	42.02	58.1
1928	73.46	27.50	37.4	45.96	62.6
1929	63.52	31.05	48.9	32.47	51.1

SUMMARY

1. The summarization of five years of growth measurement data at Kukuihaele indicates that the rate of cane growth or the growth value of a given period cannot be accurately determined by observing the color and general appearance alone and that without growth measurements such observations are apt to be misleading.

2. During the five-year period—1925 to 1929—40.12% of the annual cane growth at Kukuihaele was secured during the period November 1 to April 30.

3. Winter growth at Honokaa Sugar Company has been increased by taking advantage of the optimum moisture conditions of most of the winter months, admitting, however, that temperature is the inhibiting growth factor during winter months.

4. Comparing the five-year averages of 1925 to 1929 with the twenty-four-year averages of 1906 to 1929 shows that June, July, September and October are consistently dry, but that we can look for good rains during August.

5. Dry weather in June, July, September and October is more apt to limit the possible effects of future improvements in our agriculture than will the low temperatures of the winter months.

6. Winter growth factors are fairly stable when compared with the variable inhibiting factor of summer growth which is, of course, lack of moisture caused by wide fluctuations in monthly rainfall and inevitable periods of drought.

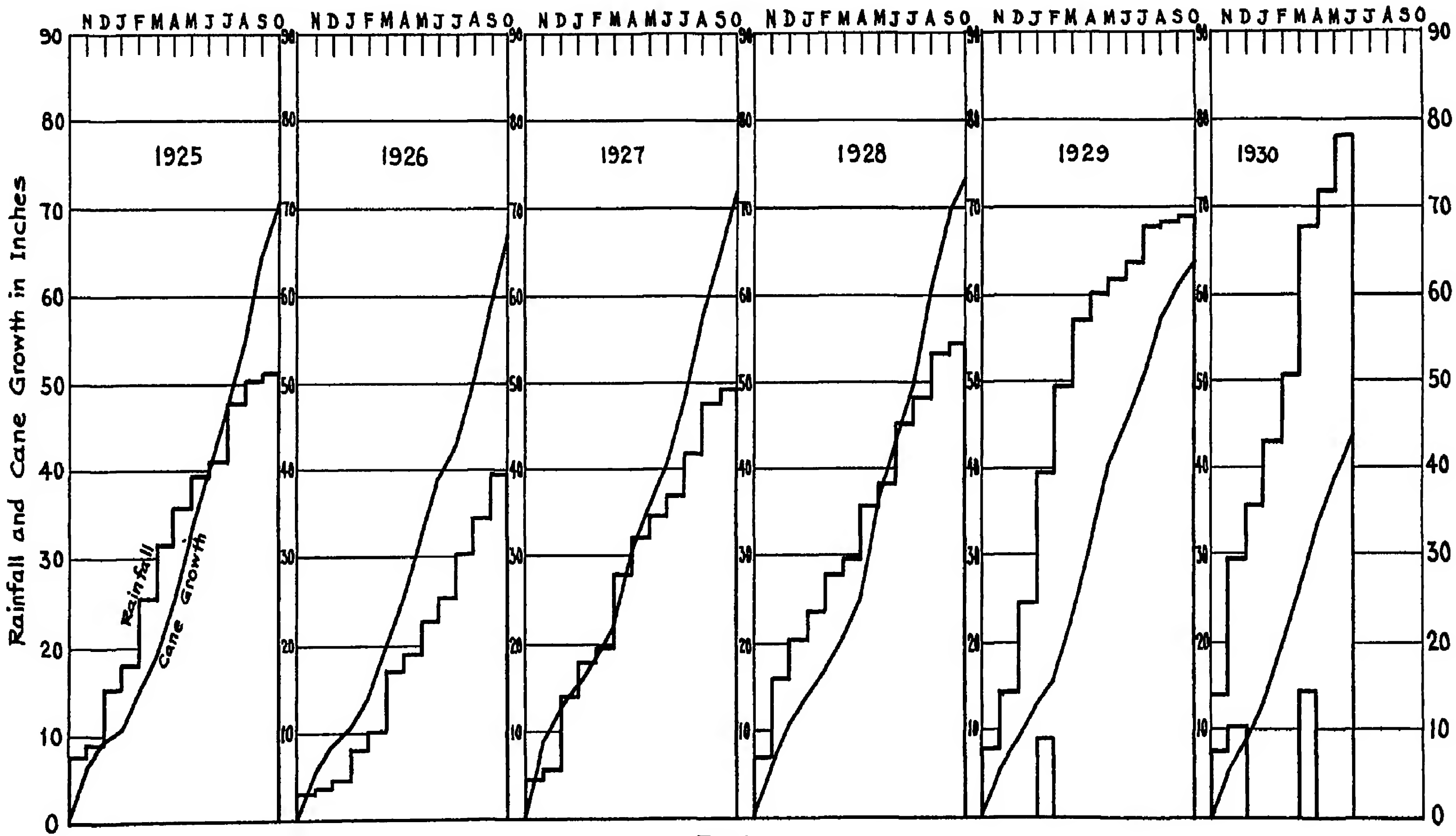

Rainfall and Cane Growth in Inches
N D J F M A M J J A S O
1925
1926
1927
1928
1929
1930
Rainfall
Cane Growth
0
10
20
30
40
50
60
70
80
90

Fig. 1

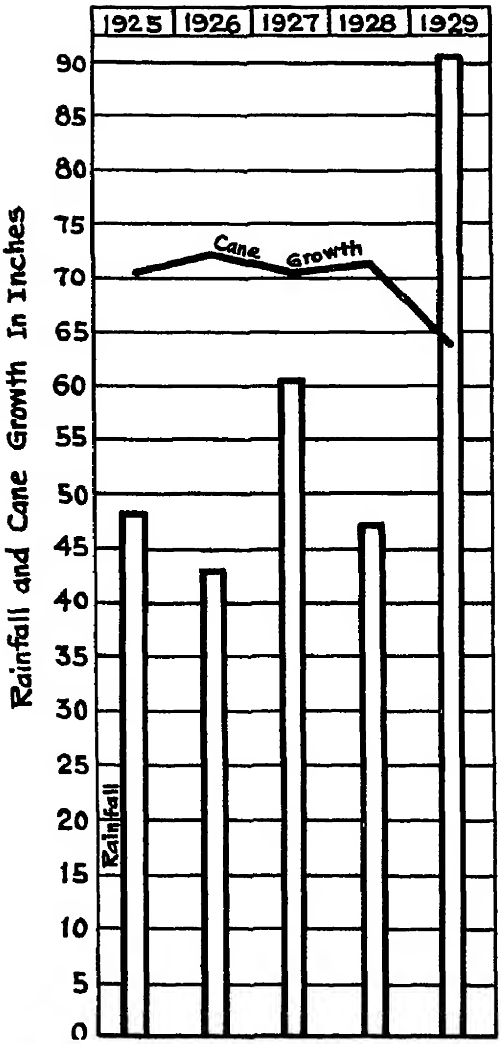

1925
1926
1927
1928
1929
Rainfall and Cane Growth In Inches
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Cane Growth
Rainfall

Fig 2

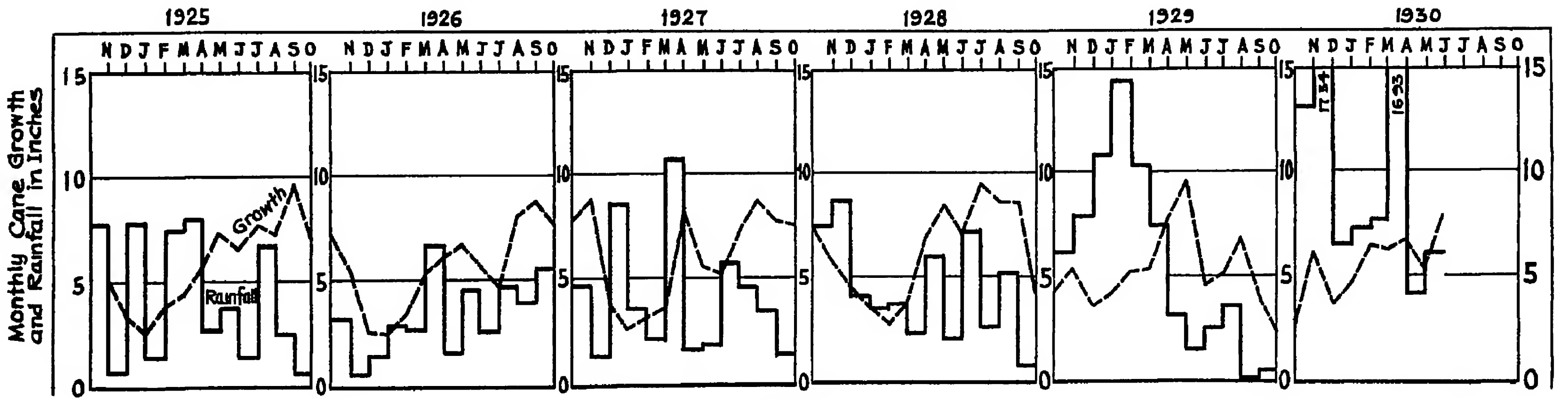
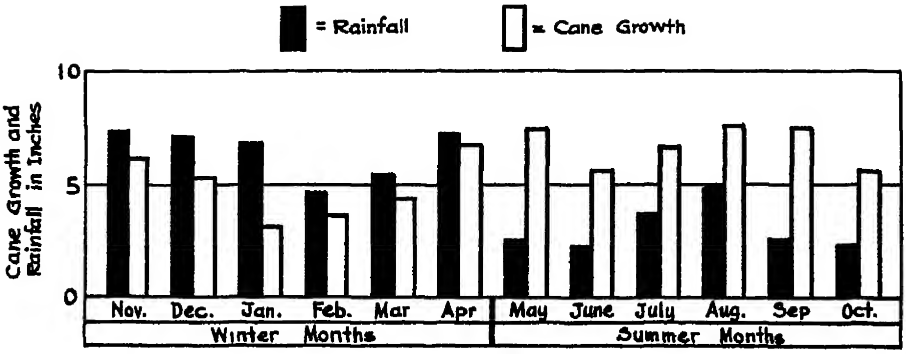
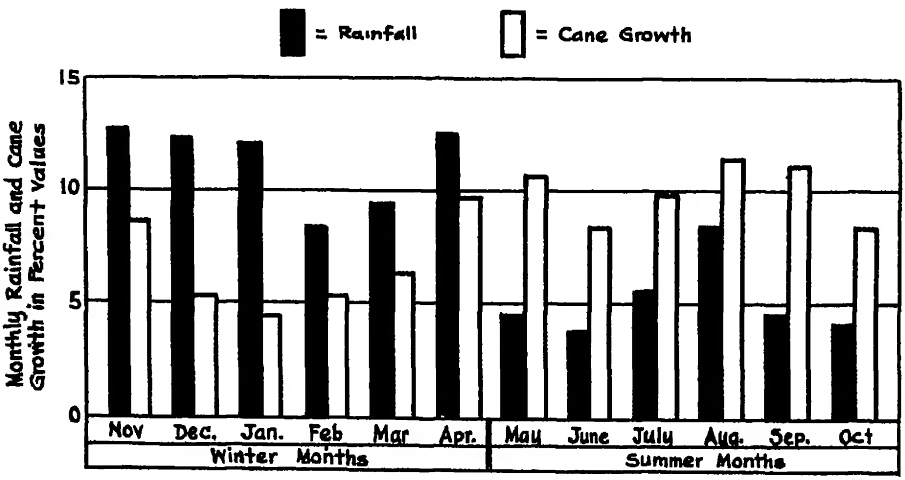

1925
1926
1927
1928
1929
1930
N D J F M A M J J A S O
Monthly Cane Growth and Rainfall in Inches
15
10
5
0
Growth
Rainfall
1734
1693

Fig 3



= Rainfall
= Cane Growth
Cane Growth and Rainfall in Inches
10
5
0
Nov.
Dec.
Jan.
Feb.
Mar
Apr
May
June
July
Aug.
Sep
Oct.
Winter Months
Summer Months

Fig. 4



= Rainfall
= Cane Growth
Monthly Rainfall and Cane Growth in Percent Values
15
10
5
0
Nov
Dec.
Jan.
Feb
Mar
Apr.
May
June
July
Aug.
Sep.
Oct
Winter Months
Summer Months

Fig. 5

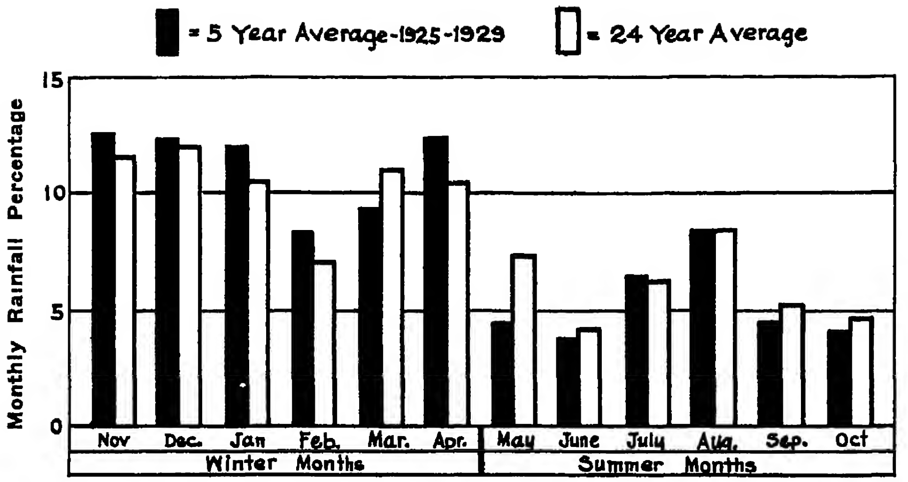

= 5 Year Average-1925-1929
= 24 Year Average
Monthly Rainfall Percentage
15
10
5
0
Nov
Dec.
Jan
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct
Winter Months
Summer Months

Fig. 6

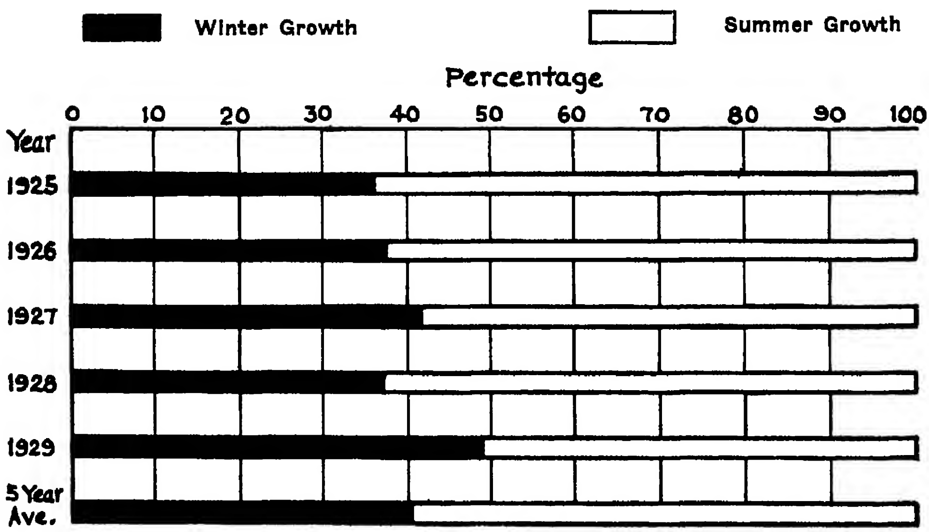

Winter Growth
Summer Growth
Percentage
0
10
20
30
40
50
60
70
80
90
100
Year
1925
1926
1927
1928
1929
5 Year Ave.

Fig. 7

Cane Varieties in the Philippines

By A. J. Mangelsdorf

Negros

Negros produces about 70 per cent of the Philippine sugar crop. A dense population, which means an abundance of labor, and a fairly uniform rainfall throughout the year are the principal factors responsible for the extensive sugar industry of this island.

Formerly Negros Purple was the only variety grown. It still occupies about four-fifths of the total area. This variety has excellent juices, is dependable under a wide variety of conditions, and is a cheap cane to cultivate. It tassels, but not excessively and we were told that it "germinates rather poorly, but not so poorly as H 109." It is an excellent ratooner. It is, however, rather susceptible to leaf scald, mosaic, Fiji disease and smut. It also suffers from excessive or deficient moisture and is not well suited to adverse conditions.

* Negros Purple and Cebu Purple are local names for one and the same cane, according to the general opinion of those familiar with them.

Badila occupies most of the remaining acreage of Negros and has been rapidly gaining in favor. It has been tried in comparison with Negros Purple in a number of yield tests. In most of these it has proved superior to the latter. Badila is very resistant to Fiji disease.

H 109, D. I. 52 and P.O.J. 2878 together occupy the remaining acreage D. I. 52 is doing well and is attracting some attention. There is some question as to its susceptibility to Fiji disease. It is not a particularly vigorous cane and it will be surprising if it should be able to compete with the sturdier varieties now under trial.

P.O.J. 2878 is attracting a great deal of attention in Negros. Atherton Lee, director of research for the Philippine Sugar Association, has reported the figures from some ten variety experiments in which P.O.J. 2878 was tested against Negros Purple, D. I. 52, Badila and New Guinea 24A, with the following results.

P.O.J. 2878 outyielded Negros Purple in each of the nine tests in which they were compared.

P.O.J. 2878 outyielded D. I. 52 in six out of eight tests. Its failure to do so in the other two tests is attributed to poor stands.

P.O.J. 2878 outyielded Badila in seven out of eight tests.

P.O.J. 2878 outyielded New Guinea 24A in each of the five tests in which they were compared.

* I am indebted to Atherton Lee, director of Research for the Philippine Sugar Association, for the estimates of acreages occupied by the different varieties, and for other information and assistance.

These experiments consisted of ten one-eighth-acre replications of each of the varieties tested. The figures may therefore be taken as quite reliable for the conditions under which the respective tests were carried out.

According to a report from the Philippine Sugar Association, at least thirty experiments comparing P.O.J. 2878 with other varieties will be harvested in Negros during the coming crop. If these bear out the results from this year's tests, we may expect to see P.O.J. 2878 taking its place as the leading variety in Negros within a very few years.

The following table gives the 1929-1930 variety census for the Hawaiian-Philippine Company. While not quite typical of the island as a whole it is nevertheless of interest.

Varieties	Hectares	Per Cent
Negros Purple	4709.02	55.60
Badila	3347.30	39.52
D. I. 52	172.60	2.04
New Guinea 24-A	113.27	1.34
New Guinea 24	27.62	.33
S. W. 3	11.21	.13
Java 247	11.71	.14
Hambledon	23.26	.27
Barbados 147	5.24	.06
Wailuku No. 2	5.09	.06
E. K. 2	5.12	.06
Malagache	1.26	.01
Rose Bamboo	1.42	.02
Bulilao	.84	.01
P. O. J. 2878	24.90	.29
H. N. 35/911 ?	2.78	.03
L. C. 25/191	.90	.01

Luzon

This island produces about 25 per cent of the total Philippine sugar crop. The climate of Luzon is not so well suited to cane as that of Negros. There is an excess of moisture during the rainy season and excessive drought during the dry season.

About three-quarters of the cane acreage of Luzon is planted to Luzon White and Pampanga Red. These two varieties are believed by many to be merely color variations of one and the same cane. They are good all around canes, thriving under a wide variety of conditions, good germinators and sparse tasselers, fairly drought resistant and have good juices. They ratoon poorly and are more or less susceptible to mosaic and to root rot, but resistant to Fiji disease and leaf scald.

In spite of the fact that these canes have certain desirable qualities, those engaged in the testing of new varieties are confident that they will soon be displaced by some of the newer varieties.

Negros Purple is second in importance on Luzon and occupies about one-fifth of the total acreage.

Of the newer seedlings which are giving promise the following may be mentioned:

Young cane suffering from drought in Luzon. To be successful under Luzon conditions a variety must be able to withstand extreme drought during the dry season, and excessive moisture during the rainy season. (Photo by J. P. Martin.)

A cane which up to now has been designated as New Guinea 24-A, but which Dr. Manuel Roxas suspects of being 147 Barbados, is being multiplied and subjected to tests as rapidly as possible. It is drought resistant and very hard. It bends rather than breaks in high winds, and suffers less from typhoon damage and from rat damage than most canes.

Mauritius 1900 is another cane which is attracting attention. It is described as having very good juices, is markedly drought resistant, and a sparse tasseler. It is a short thick type. One of its weaknesses is its susceptibility to mosaic. It is also susceptible to Fiji disease and leaf scald but these two diseases can be casily controlled, according to the plantation men.

P.O.J. 2878 does not look particularly outstanding on Luzon. If one may judge from the plantings seen here it cannot compete to best advantage under conditions of extreme drought or poor soil. According to Dr. Roxas it is not entirely resistant to mosaic and leaf scald and is rather susceptible to Fiji disease. It tasseled up to 60 per cent in 1928-1929. This is considered a great disadvantage because the planters depend for planting material on top seed cut from their harvesting fields. The fact that the native varieties rarely tassel and thus can be relied upon for good top seed at harvesting time is one of the principal reasons for their popularity. The Philippine hacenderos apparently have not learned, as those of Formosa have, to make planting entirely independent of harvesting by the use of seed nurseries to serve as a source of planting material. Seed nurseries have enabled Formosa to successfully utilize P.O.J. 2725—a variety which tassels practically 100 per cent.

We were told that certain fields of P.O.J. 2878 on Luzon had suffered rather severely from typhoon injury and contained much rotten cane when harvested.

On the whole P.O.J. 2878 is not gaining favor on Luzon nearly so rapidly as on Negros. It is not impossible, however, that it may not yet prove to be superior to the present varieties.

H 109 is being grown to a limited extent. It has the reputation of germinating rather poorly in comparison with the native varieties under the dry planting conditions commonly met with. The growers also object to its free tasseling. However, it ratoons better than most varieties under Luzon conditions and it has good juices even at an early age.

P.O.J. 213 is doing well on rather poor soils at Del Carmen.

P.O.J. 2714 and P.O.J. 2727 are being tried, but neither appears outstanding. It is probably too dry for the former, while the latter is very susceptible to Fiji disease.

P.O.J. 2725 which is doing so well under very similar conditions in Formosa has just been imported and is still in quarantine.

Chinois—a Uba cane imported from Saigon, and which Dr. Roxas believes to be identical with our so-called Hawaiian Uba, has given good yields in situations so poor that other canes refuse to grow. The factories discourage the farmers from planting it, however, because of the difficulties in milling.

Yellow Caledonia was planted on rather a large scale on Luzon several years ago but it proved to be susceptible to Fiji disease. The prolonged dry season, too, is probably not to its liking.

Mindoro, Panay and Cebu

These three islands have altogether five centrals, which grind less than 5 per cent of the total Philippine sugar crop.

Mindoro has the largest acreage of H 109 in the Philippines. This variety, according to Mr. Lee's estimate, comprises about half of the total acreage there, with P.O.J. 213 about 20 per cent and Uba about 5 per cent. The native varieties, Luzon White and Negros Purple make up the remainder.

The acreage on Panay is about 85 per cent Negros Purple, 10 per cent D. I. 52 and 5 per cent P.O.J. 2878.

The acreage of Cebu is 100 per cent Negros Purple.

Summary

The principal variety on Negros is Negros Purple. Badila is second in importance and has been gaining in favor. More recently P.O.J. 2878 is attracting much attention. According to present indications it will replace the varieties now being grown on Negros within a few years.

Luzon White and Pampanga Red are the principal varieties on Luzon. These are believed to be color variations of one and the same cane. Negros Purple is second in importance.

Mauritius 1900 and a cane known as New Guinea 24-A (147 B?) have been outyielding the older varieties in tests and are gaining favor.

P.O.J. 2878 has not established itself as rapidly on Luzon as on Negros. However, it may still prove superior to the present varieties.

H 109, P.O.J. 213 and Uba are also grown to a limited extent on Luzon.

The plantings on Mindoro, Panay and Cebu comprise only a small percentage of the total.

The Mindoro acreage consists of H 109, P.O.J. 213, Uba, Luzon White and Negros Purple.

The Panay acreage is planted chiefly to Negros Purple, with a small percentage of D. I. 52 and P.O.J. 2878.

The Cebu plantings consist almost entirely of Negros Purple.

It is quite generally felt that the old native varieties which have dominated the Philippine plantings for so many years will be replaced by canes of greater yielding ability in the near future.

Sugar Cane Breeding in the Philippines*

By A. J. Mangelsdorf

Luzon White and Negros Purple have long been the standard varieties in the Philippines. With their high sucrose content and their tolerance of unfavorable conditions they met very satisfactorily the needs of the industry as it was conducted in the old days.

With improved field practices, however, came the desire for varieties better able to respond to the improved methods. This desire has supplied the necessary incentive for a beginning in cane breeding work.

The growing of seedlings was begun by Dr. N. B. Mendiola, at the College of Agriculture at Los Banos, in 1919. Although seedlings were produced only in limited numbers as compared with some of the other sugar cane countries, much valuable work was done in the development of breeding methods.

More recently the Philippine Sugar Association has undertaken a program of seedling production. Their first crosses were made during the 1927 and 1928 crossing season. The production of seedlings is now being prosecuted by the Association on an extensive scale.

Crossing Methods

The usual method of effecting crosses is similar to the one designated in the Java literature as free crossing. The female tassel is allowed to remain on its own stalk. Shortly before tasseling the female stalk may be trained along the ground so that the tassel, when it emerges, will be in a convenient position for pollination. When the female tassel begins blooming two male tassels are cut, usually late in the afternoon, and are tied in a position so as to surround the female tassel as completely as possible.

Formerly it was considered necessary to suspend a bamboo vase in such a position that the cut ends of the male tassels would be immersed in water. Recently, however, it has been found that if cut late in the afternoon the male tassels will shed their pollen the next morning without being placed in water.

A second method which has been used to a limited extent is an adaptation of the Indian procedure of surrounding several joints of the tasseling stalk with earth, thus inducing it to send out roots, after which the stalk is cut below the "layered" portion and removed to an isolated spot for crossing. Instead of using a clay pot to hold the earth around the stalk as in India, a joint of bamboo of large diameter is used for this purpose. The bamboo joint has several advantages over the Indian clay pot, being lighter in weight, not easily broken, and drying out less quickly.

A third method which has been used with fair success is that of collecting the pollen from the male tassels each morning by shaking them over a sheet of Manila paper. The pollen so collected is then carried to the female tassels and dusted upon

* I wish to express my thanks to Dr. Manuel L. Roxas, Dr. N. B. Mendiola, and others, who supplied the facts reported in this paper.

the newly emerged stigmas. Good germinations are reported from tassels pollinated in this way.

The sulphurous acid method of Hawaii is being followed with good success at Victorias.

Crossing under bags has been used to a very limited extent only. As in most other countries this method has been largely replaced by others because of the poor germinations which usually result from bagged tassels.

At Los Banos, plantings of breeding canes have been made at elevations of 300 and 1500 feet on the slopes of Mt. Maquiling. These differences in elevation have been found to influence the time of tasseling to such an extent that it has been possible to make crosses which would have been out of the question had the two parent varieties been grown at the same elevation.

Varieties Used as Parents

In the early stages of the seedling work at Los Banos, field collected tassels were used and no parentage records were kept. In recent years, however, complete pedigrees have been kept of the seedlings produced.

Dr. N. B. Mendiola, of the College of Agriculture at Los Banos. Dr. Mendiola and his students have contributed much to the progress of cane breeding in the Philippines.

H 109 has been rather extensively used as a female parent by the Philippine Sugar Association because of its good juices and good ratooning ability.

Hind's Special, a cane which is grown by the Negritos in the mountains of Zambales is being extensively used as a male parent. There is some evidence that it is a natural hybrid between one of the noble canes and the native Philippine form of *Saccharum spontaneum* known locally as "Talahib." Hind's Special is a hardy, vigorous cane and is said to have very fair juices.

Toledo, another cane which is believed to be a chance *spontaneum* hybrid is also being used to some extent in crosses. It tends to have poor juices but it is quite vigorous.

Badila, contrary to its usual behavior in Hawaii, tassels very freely in the Philippines and is widely used as a male parent.

Attempts have been made to use the Uba canes in breeding work, but as in Hawaii they have proved rather highly sterile and have usually given only a few seedlings. In 1929, however, several hundred seedlings per tassel were reported from Chinois, a Uba from Saigon, crossed with New Guinea 24A.

C.A.C. 87 is a thin, vigorous cane which is being extensively used as a male parent in crosses with the noble canes. Like Toledo and Hind's Special, it is believed to be an accidental hybrid between one of the thick canes and Talahib. Its appearance bears out this theory—it resembles Kassoer and U. S. 666 (a Kassoer seedling) quite closely.

Surprisingly enough the two principal Philippine varieties, Luzon White and Negros Purple have been little used in breeding work. These two canes have some desirable qualities, which if transmitted to their seedlings, should make them valuable breeding material. We refer especially to their good juices and their tolerance of drought and other unfavorable conditions. The sparse tasseling of Luzon White is also a very desirable quality which adds interest to this cane as breeding material.

More recently the Java canes, P.O.J. 2878 and P.O.J. 2883 are being used in crosses in the Philippines. Dr. Dwight Pierce, who was formerly associated with the Victorias Milling Company of Negros, told us that P.O.J. 2883 crossed with Badila has given them more promising seedlings than any other combination tried thus far.

Nursery Methods and Selection Procedure

The climate of the Philippines is, of course, much more tropical than that of Hawaii, and the germinating equipment, such as greenhouses and heated tables which we have found essential in Hawaii are unnecessary there. The fuzz is sown in low boxes, which are kept covered with panes of glass until the seedlings have become established.

Up to the present time it has been the practice to prick out the seedlings into other flats when they have reached the age of a month or so. At present, however, pricking into nursery beds is being tried, as in India, and with good success.

When they are three to five months old the seedlings are set out in the field. Here the rows are 40 inches apart and the seedlings are spaced 30 inches apart in the row.

The first selection is made when the seedlings are about a year old. Disease resistance is considered the most important point to be watched. Seedlings found to be infected with mosaic or other diseases are eliminated at once. The percentage infected with mosaic is usually high. Seedlings from crosses involving wild (*Saccharum spontaneum*) blood have been found to show a much smaller percentage of mosaic infection than other crosses.

Tasseling is considered a serious disadvantage and canes which tassel heavily are eliminated. This policy is based on the fact that the growers depend on the harvesting fields for their planting material. Tasseling results in seed which is unsatisfactory both in quality and quantity.

Splitting of the rind is considered a serious defect. It is believed that these splits permit the entrance of red rot infection.

Erect canes are preferred—those which lodge are discriminated against. Lodging usually results in serious deterioration in the Philippines, due to breaking of stalks, followed by rat damage and subsequent rotting. Canes of medium length or less, which compensate for their lack of length by free stooling are preferred for this reason.

Good juices and satisfactory milling qualities are also listed among the more important qualities to be looked for in seedling selection.

Out of a list of 20,000 seedlings grown by the Philippine Sugar Association in 1928 at Canlubang and Del Carmen, 400 (about 2 per cent) were retained after the first selection. Fifteen to twenty cuttings were taken from each and planted out to a second trial. No check rows were used in this second planting but we were told that in the future such tests will contain alternate rows of a standard variety for comparison.

NUMBER OF SEEDLINGS PRODUCED

While the success or failure of cane breeding work is by no means determined by the number of seedlings grown, it is of interest to examine the census of seedlings produced to date.

Grown by the College of Agriculture at Los Banos:

Year	No. of Seedlings Grown
1920	4,377
1921	223
1922	755
1923	743
1924	2,756
1925	1,325
1926	50,000*
1927	100
1928	14,412
1929	5,000

Grown by the Philippine Sugar Association at the Del Carmen and Canlubang Station.†

1928	20,000
1929	15,000

Grown at the La Carlota Sugar Cane Experiment Station:

Up to 1929	12,608

Approximate total for all stations—127,300††

* Of this number, 20,000 were sent to the Philippine Sugar Association Station at Del Carmen and 10,000 to Pasudeco.

† Approximate.

†† In addition to the above the Victorias Milling Company has produced a number of seedlings, the exact figures for which are not at hand.

The following list shows the number of seedlings grown by the Philippine Sugar Association in 1929, with their parentages. It is interesting to note that a wide range of parents is being used including several which are highly regarded as breeding canes in other countries. It is evident from this list that the importation and use of breeding material is receiving considerable thought and attention.

Parentage	No. of Seedlings Set Out
H 109 x Co. 205 (1)	7,511
H 109 x P. S. A. 7 (2)	1,052
H 109 x P. S. A. 143	366
H 109 x P. S. A. 3	56
H 109 x Cane X-4	344
J 247 (3) x Co. 205	1,340
J 247 x Co. 205	501
J 247 x Hind's Special	293
D 1135 x Co. 205	675
N. G. 24A x Hind's Special	613
N. G. 24A x Cane X4	40
Cebu Purple x Co. 205	102
Lahaina x Co. 205	193
Lahaina x Co. 206	18
Lahaina x Hind's Special	226
Lahaina x C. A. C. 87 (4)	153
Rose Bamboo x Co. 205	226
Badila x Hind's Special	201
Badila x P. S. A. 19	18
Louisiana Striped x Co. 205	89
P. S. A. 7 x H 109	84
Mauritius 1900 x Hind's Special	77
Q 409 (5) x Hind's Special	77
Q 409 x C. A. C. 87	36
C. A. 12735 x Cane X 4	40
Chinois x N. G. 24 A	79
Chinois x Badila	12
Toledo x J 247	227
Toledo x H 109	224
Toledo x C. A. 12735	151
Toledo x Badila	52
Total	15,166

Breeding Work at La Carlota and Victorias

The following notes, kindly supplied by Dr. Roxas, give a review of the breeding work at the La Carlota Sugar Cane Experiment Station, at La Carlota, Occidental Negros. This is a Government Station under the direction of the Bureau of Plant Industry.

(1) Co. = Coimbatore.
(2) P. S. A. = Philippine Sugar Association.
(3) This refers presumably to the Java cane 247 B.
(4) C. A. C. = College of Agriculture cane.
(5) Q = Queensland.

The total number of sugar cane seedlings produced in the station since the beginning of the work is 12,608.

The total number of seedlings eliminated so far is 10,361.

The total number of seedlings now being propagated is 2,247.

The five most promising seedlings are the LC 22/4, LC 25/191, LC 25/138, LC 25/210 and LC 25/476.

The method of crossing is by natural hybridization, that is, hybridization without emasculation.

The method of selection is by elimination of the poor strains.

The qualities looked for in parents are high tonnage of cane, high sucrose content, resistance to prevalent diseases and pests, resistance to drought and excessive water, etc.

A letter from Carlos Locsin to Dr. Roxas gives some interesting comments on the breeding work at the Victorias Milling Company, Occidental Negros. We quote from it as follows:

> This is only our third year of seedling work. My two promising seedlings of the first year are only on their way to preliminary trial and the second year seedlings will not come to the test for juice quality until February. So that really there is hardly anything to talk about. I have even avoided mentioning any results of this work in my report on experimental work on sugar cane.
>
> As to breeding methods, we have used free crossing in the field, layering by bending the stalks in the ground and getting the two arrows to be crossed together in the field, potting soil around the cane stalks and crossing under shed and finally the sulphurous acid method. I prefer this last method and used it extensively this year. Next year I plan to use this method exclusively preparing our stock solution in the laboratory. This year some of the solution we used was locally prepared and some from 8 per cent stock solution brought from the States. Undoubtedly the solution loses strength on the way as we find only around 6 per cent of the sulphurous acid in the solution upon arriving at Victorias. A breeding rack that will hold the canes and keep the solution bottles under cover is a great convenience. A model of such a rack was illustrated in one of the recent issues of *Facts About Sugar.*
>
> We find the common red Victorias soil perfectly suitable for use in the seed germinating boxes. It drains well and does not harden. We mix it with some press cake, sterilize and sift it before use. From the original seed boxes we transplant the seedlings in a second series of boxes when about 4 to 6 inches high and from there to the field when sufficient root system has developed. We use a field of red Victorias soil for growing the seedlings. Very few seedlings are lost from transplanting. This year I made up my mind to try transplanting from the original seed boxes to the field to save one transplanting operation. I think under conditions here this can be done with very little loss of seedlings.

List of Philippine Seedling Series

It may be well to record here the various series of Philippine seedlings:

The P. B. (Plant Breeding) series are temporary numbers given to selected seedlings by the College of Agriculture.

The C. A. (College of Agriculture) series includes the canes which were selected and given permanent numbers during the first few years of seedling work. In the future those receiving permanent numbers will be designated C. A. C. (College of Agriculture Canes).

The P.S.A. seedlings are those selected by the Philippine Sugar Association.

The L. C. seedlings are those selected by the La Carlota Sugar Cane Experiment Station.

The C. S. E. seedlings are presumably those selected by Calamba Sugar Estate. (This is based on surmise only—we have no information on this series.)

Results Obtained

In view of the fact that the breeding work was begun only some ten years ago, too much cannot be expected as yet in the way of results.

The testing of seedlings is a slow process,—one in which time is a very necessary element. It is only by following the performance of a seedling through a succession of crops that its value can be determined.

In this respect the Philippines have an advantage over Hawaii in that twelve-month crops are the rule as compared with our sixteen- to twenty-four-month cycles. On the other hand, the selection work there cannot proceed as rapidly as in Java, where only plant crops are grown. In the Philippines, as in Hawaii, ratooning ability is an important consideration, and the necessity of testing the seedlings for their ratooning ability prolongs the selection period.

Of the seedlings produced in the earlier stages of the work, a small number have been selected as showing promise: C.A.C. 111, P.S.A. 3, 6, 7 and 14, C.A. 12735 and 15723 are especially mentioned.

To these should be added the La Carlota seedlings L. C. 22/4, 25/191, 25/138, 25/210 and 25/476 and the Victorias seedling "Esperanza de Victorias."

None of the above seedlings are being grown on an extensive scale as yet, and it remains to be seen whether any of them will be able to displace the present varieties.

It seems certain, however, that if the breeding work is continued on its present scale the development of seedlings better suited to Philippine conditions than the canes now being grown is only a matter of time and persistence.

Summary

Cane breeding in the Philippines was begun by Dr. N. B. Mendiola, of the College of Agriculture, at Los Banos, in 1919.

Relatively few seedlings were produced during the first five or six years. During this period attention was centered chiefly on the development of crossing and nursery technique.

The Philippine Sugar Association now has under way a program of breeding work and is producing seedlings on an extensive scale.

The La Carlota Sugar Cane Experiment Station and the Victorias Milling Company on Negros are also growing and testing seedlings.

Of the local canes, Luzon White, Negros Purple, Hind's Special, C. A. C. 87 and Toledo appear to have characteristics which make them of special interest as breeding material. These together with the large number of varieties imported from other countries afford an excellent assortment of material for breeding work.

Between 100,000 and 200,000 seedlings have been grown since the beginning of the work.

A few of the earlier seedlings are showing promise, and are being tested against the present varieties.

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An Open Letter to All Sugar Technologists*

At the Third Congress of the International Society of Sugar Cane Technologists, held at Sourabaya, Java, in June, 1929, the following resolution was unanimously adopted:

> Whereas, the current technical literature on sugar cane and beet is published in a large number of periodicals and often is written in a language which is only understood by a minority of the technologists or is not available in the local libraries;
>
> Whereas, further reinforcement of interest of organizations and of the personal members of our Association is desired for further development of the activities of the Association;
>
> Be it resolved, that a new periodical be started containing (or an existing periodical be requested to print) adequate abstracts in the English language, submitted by the authors themselves of all technical papers of more general importance;
>
> And be is further resolved, that a committee be appointed by the chairman to devise ways and means for carrying this resolution into effect.

Publication Plan Adopted

The committee appointed in accordance with this resolution and consisting of H. P. Agee (Hawaii), chairman; K. Douwes Dekker (Java), R. Fernandez Garcia (Porto Rico), A. H. Rosenfeld (Louisiana), and W. B. Saladin (Cuba), has given this project very careful consideration, and has discussed a number of plans. The first of the two methods mentioned in the resolution, viz., publication of such a journal under the financial responsibility of the Society itself, has been deemed to be impracticable in the present status of our Society, because the latter has no funds available to apply to such an undertaking, and a campaign for the needed funds, even though possible in itself, would greatly delay the launching of the periodical. The second plan, however, appears feasible immediately, and the chairman of the committee, with the approval and consent of the other members, has authorized the general chairman of the Society to enter into negotiations with E. W. Mayo, Editor of *Facts About Sugar*. A preliminary conference accordingly has been held between Mr. Mayo and the general chairman of the Society, and the former has agreed to publish all abstracts which the Society may furnish through any or all available channels. A section with appropriate heading will be set aside, and pursuant to the wishes of the committee, abstracts concerning the agricultural phase of the cane sugar industry will be separated from those relating to the manufacturing side. Owing to the character of the Society, sugar beet growing for the present will not be considered, but it is desired to include beet sugar manufacture, because in the manufacturing field the problems of the two industries are in many instances quite similar.

Supply of Abstracts

Turning now to the question of the abstracts themselves, it has been the custom with journals of a similar character to employ paid abstractors, each one of them taking care regularly of a certain number of journals of a certain specialized

* Taken from *Facts About Sugar*, Vol. XXV, June, 1930, pp. 579-580.

branch of knowledge. The Society is at present financially unable to pursue such a course. But it is believed, and this belief is expressed in the text of the resolution, that every author who is interested in having his work published and made known to the world is quite as much interested not only in securing as large as possible a circle of readers for his own publications, locally as well as universally, but also in having ready and convenient access to all the literature in his field appearing anywhere in the world, in any language. After an author has taken considerable time to collect his data and to put them down in words, it requires only an additional fraction of the time consumed to prepare an abstract giving the salient features of the article. It is often said that trained abstractors are better able to do this than many of the authors themselves. While this may be generally true, the writer has noticed not a few instances where an abstractor has missed a point or misconstrued the statements of an author. Another important point is that abstracts, in contradistinction to critical reviews, should be informative only, and the preparation of the abstracts by the authors themselves safeguards this feature. A certain amount of editing of the abstracts is necessary, to be sure, in order to guarantee a uniform policy; this part of the work will be handled by the Technical Editor of *Facts About Sugar*, in cooperation with the officers of the Society.

The cooperation of all the sugar journals all over the world, of government departments, experiment stations, local technologists' associations, etc., will be necessary and is earnestly solicited. In some cases it may be possible to make special arrangements with established abstract journals to reprint abstracts of articles appearing in other than sugar journals, which are of interest to sugar technologis's, such as, for instance, on sugar chemistry, plant physiology, phytopathology, the various branches of engineering, and such like.

The Editor of *Facts About Sugar* has also offered to furnish reprints of the abstract pages at cost, in the more handy form of 15 x 23 cm., with two columns instead of three. An exact price per year cannot be fixed until it is known how much space will be required.

Cooperation Necessary to Plan

The success of the journal will depend entirely on the interest shown and on the amount of cooperation given by each member of the Society and by each author, whether or not he is a member of the Society.

The publication of the abstracts will begin as soon as a sufficient number is received by the Editor of *Facts About Sugar*, 153 Waverly Place, New York City. Orders for subscriptions to the reprints should also be addressed to him. It is intended to include all articles which have appeared since January 1, 1930, so as to have a complete record for the present calendar year. Authors please note!

A supply of copies of this letter will be sent to each vice-chairman of the Society, and they will be requested:

(1) To distribute these copies among the members of the Society. Additional copies will be sent on request.

(2) To point out to all sugar technologists in their territory the necessity of sending in abstracts of all articles they publish, not later than the time they appear in print. In some cases where publication is liable to be delayed, it will be preferable to forward the abstract when the article is transmitted to the publisher; the abstract will in such cases be held at the office of *Facts About Sugar* and the reference inserted after the article has actually been published. General directions concerning the nature and style of the abstracts are given below: they are patterned after those adopted by *Chemical Abstracts.*

(3) To examine periodically all the technical sugar literature published in their territory and to ascertain whether all of it has been abstracted and abstracts have been forwarded. If any articles have been omitted, the vice-chairman is requested to send the titles of them to the Editor of *Facts About Sugar,* preferably accompanied by the abstract.

The vice-chairmen are further requested to notify the Editor of *Facts About Sugar,* on the return card sent to them, whether they are willing to cooperate in the way indicated above. If for any reason they are unable to undertake these duties they are expected to appoint a committee of one or more members in their territory who express a willingness to act in that capacity.*

Any articles noted in the literature by the Technical Editor of *Facts About Sugar,* for which articles no abstracts have been received in a reasonable time, will be reported by title only. It will therefore be to the interest of each author to send in abstracts promptly. The responsibility for the success of the new venture rests upon each individual sugar technologist.

F. W. Zerban,
General Chairman.

GENERAL DIRECTIONS FOR ABSTRACTING

Nature of Abstract—The abstract should contain all important new information in sufficient detail to give a clear idea of what has been accomplished. The general reader should not find it necessary to refer to the original, and the specialist should be able to judge from the abstract whether or not he will have to do so. Abstracts of articles which originally appear in any of the less known languages, especially those of the Slav and Asiatic groups, should generally be given in greater detail. The abstracts of technical research work should not be in the form of summaries merely stating the subject treated and the results obtained, but should be analytical in nature, along the following general plan. They should include, in the order given, a statement of:

(1) The purpose of the investigation.

(2) The methods by which the worker has approached his subject, and by which he has obtained a solution of his problem.

(3) The results actually obtained, and the conclusions drawn by the author of the article.

* Note—The following committee has been appointed to deal with abstracts for the Hawaii branch of the International Society of Sugar Cane Technologists: J. P. Martin, A. J. Mangelsdorf, O. H. Swezey, F. E. Hance, H. L. Lyon, W. R. McAllep. (H. P. A.)

Such analytical abstracts are not necessary in the case of articles which merely represent discussions, restatements, or reviews of the literature, new books or monographs, criticisms of other articles, etc. In these cases descriptive abstracts will usually suffice, each individual instance to be judged separately by the author and editor

Language—All the abstracts are to be published in English, but if the author who prepares the abstract is not sufficiently conversant with that language, they may be sent in in Dutch, French, German, or Spanish, and such abstracts will be translated through the editorial office.

Abbreviations—No abbreviations should be used by the authors. The editor may introduce suitable abbreviations, a key to which is to be printed in the journal

Manuscript—Whenever possible abstracts should be typewritten, double spaced, on one side of the paper only If the author is unable to furnish typewritten copy, he should write as legibly as possible.

Heading of Abstract—The headings should invariably be given in the following order:

(1) Title of article.

(2) Full names of author or authors.

(3) Name of journal.

(4) Serial number of the volume of the journal.

(5) Page number on which the article begins and page number on which it ends, with a dash between the two, thus: 512-625.

(6) Year in which the article has been published, in parentheses, thus: (1930).

An example follows:

Polarization apparatus with photo-electric indication. W. E. Dickes. Z. Zuckerind. Czech. Rep. 51, 379-80 (1927).

Tables, Graphs, and Drawings.—These should be used only when the information cannot be given in words in less space. In some cases graphs and drawings may actually save space; they should be sent in such form as to be reproducible without redrawing.

Reference—References to previous literature should always be given, to assist the research worker. As soon as this journal has become established, reference should be made to abstracts previously appearing in it.

Rat Control in Hawaii

By C. C Barnum

Introduction

Since the publication by this Station of the Entomological Series Bulletin 17, dealing with "The Field Rat in Hawaii and Its Control," by C. E. Pemberton, in June, 1925, there has been nothing published in Hawaii relative to rat control excepting progress reports appearing from month to month in the Director's *Monthly Letter*. These progress reports first appeared in October, 1928, and continued until June, 1929, covering the period during which the investigations herein reported were conducted.

This paper presents a general review of previous work done here and elsewhere on rat control and, in detail, the results of an eight-month investigation on rat control conducted on the island of Kauai. The investigations on Kauai were begun at the request of J. T. Moir, Jr., manager of The Koloa Sugar Company, Koloa, Kauai, who offered every facility during the period of study for the continuation of the problem and who put into practice during this time the practical recommendations which have proved effective in controlling the rat population at The Koloa Sugar Company and elsewhere.

Damage Caused by Rats

Damage by rats to produce and property in the United States amounts to about $200,000,000 annually On certain plantations in Hawaii it has been estimated that 20 per cent of the stalks showed rat injury. In one instance the losses were estimated on one plantation to be 25 per cent to 40 per cent of the crop while similar losses have doubtless been suffered by several plantations in other locations. The damage done by rats on the coffee plantations of Kona has been estimated at $75,000 to $100,000 annually. The rats remove entire branches bearing fruit and eat only the ripest coffee berries. The injury is considerable in that the fruit-bearing wood is lost as well as the crop. The losses in grain and food materials stored in barns and warehouses throughout the Territory are often considerable.

Kinds of Rats

There are in Hawaii three distinct species of field rats, which are classified as follows:

The gray rat, *Rattus norvegicus* (Erxlelen).

The black rat, *Rattus rattus* (Linn.).

The white-bellied black rat, *Rattus rattus alexandrinus* (Geoffroy).

The gray rat is predominant and is the largest of all at maturity. It eats the most food. A large gray rat will eat one pound of sugar cane daily. Three

healthy adult wild gray rats were caught and separately caged. Each rat was fed daily for six successive days one pound of sugar cane which was cut into short lengths and split open to facilitate mastication. Each rat was provided with a daily supply of drinking water. On the seventh day the cane had all been eaten in each cage. Under field conditions probably more cane is consumed daily by each mature rat.

The tail of the gray rat is shorter than his body and the ears are smaller than those of the black rat. This rat is variously named the brown rat, wharf rat, sewer rat, migratory rat, or Norway rat. The average body weight of an adult gray rat is 325 grams or 0.7 pound.

The black rat, or house rat, eats almost as much sugar cane per day as the gray rat, but is somewhat smaller in size. The white-bellied tree or roof rat is a subspecies of the black rat. Both the latter rats have tails longer than the bodies and have very large prominent ears. Pemberton (1) states that the three species of rats above named, were introduced into Hawaii by sailing ships in the nineteenth century.

The practically extinct native Hawaiian rat, *Rattus hawaiiensis*, as described and named by Stone (2), may still exist on outlying coral islands and reefs, but is extremely rare throughout the inhabited parts of the islands. Living specimens of this species have been trapped in 1915 and 1917.

Rats and Bubonic Plague

All rats may carry fleas. Rats are subject to bubonic plague. Fleas carry bubonic plague germs from rat to rat. When a rat dies of plague the fleas leave the dead body and preferably move to the body of a living warm-blooded animal. Should such fleas choose a human being as host that individual would probably be bitten by the fleas in a short time. Such bites often result in the development of plague symptoms within a few hours. A person affected with plague seldom recovers. The rats examined by Pemberton (1) at Honokaa carried the true plague flea, *Xenopsylla cheopsis* (Rothchild). On one rat thirty-two plague fleas were found. The "Black Death" of London in 1665 was a very severe epidemic of bubonic plague in which over half of the population of London was wiped out. The rats acted as mechanical carriers of the disease and the fleas as transmitters of the infection. The causal organism of plague, *Bacillus pestis*, forms such large groups of bacilli as to plug up the entrance to the stomach of the flea. As pointed out by McCallum (3) in his text, such fleas being constantly hungry, will bite again and again, each time transferring plague bacilli to the victim.

Plague exists at present along the Hilo and Hamakua coasts of Hawaii, and so far as known at present nowhere else in the Territory of Hawaii. Plague first appeared on the island of Hawaii in Hilo in 1900, when five human cases occurred. Eleven people died of plague on the Hamakua coast in 1922. Eight persons died of plague during the year ending June 30, 1928, as reported in the Annual Report of the President of the Board of Health of the Territory of Hawaii for that period. The Territorial Board of Health maintains, under the supervision of C. Charlock, Chief Sanitary Inspector, a laboratory at Hilo to which

all rats trapped along the Hilo and Hamakua coasts are shipped daily. The rats are dissected and carefully examined each day at the laboratory in Hilo. Every rat is tagged at the time of removal from the traps; the tag indicates the exact location where each rat was trapped. The bodies of these rats are examined for any symptoms of plague. Should any lesions be found that would indicate a case of plague, direct inoculations are immediately made into guinea pigs kept for this purpose. Laboratory tests are also made to determine the presence of the plague bacillus in the lesions. During the year ending June 30, 1928, twelve rodent plague cases were determined.

Should these guinea pig inoculations prove positive the region where this particular rat was caught is heavily poisoned or extensively trapped, or both, in order to exterminate the rat population in that locality as soon as possible. The constant systematic investigations of the Board of Health have undoubtedly prevented severe epidemics of plague during recent years. Pemberton (1) holds that plague-infected rats are more numerous in dry years than in similar periods of heavy rainfall.

Breeding Habits

Rats multiply rapidly. A single pair of rats may produce a progeny of 800 rats in a single year. This is due to the early maturity of the young. Sexual maturity is reached at 3 to 4 months. The period of gestation is 21 days. The average litter of young is 10.

The ratio of males to females is generally considered about equal. Of rats trapped in Hawaii, the majority have been females.

Natural Enemies of Rats

Dogs and cats are common enemies of rats and doubtless kill many. Dogs, especially at harvest time, kill large numbers of rats in the harvest fields. The effect on the rat population is, however, negligible.

Pemberton (1) points out the value of the mongoose, *Herpestes griseus,* in rat control. This animal, a native of India, was introduced into Jamaica in 1872. The mongoose was introduced into Hawaii, Maui and Oahu in 1883 direct from Jamaica, West Indies, for the purpose of controlling the rats. No introductions were then made or have since been made into Kauai. The result has been that the observed rat damage on Kauai in 1927 and 1928 was uniformly higher than on either Oahu, Maui or Hawaii.

Pemberton (1) in determining the diet of the mongoose, found that it consisted primarily of rats, mice and cockroaches. In some countries rats are partially controlled by snakes. No snakes exist in Hawaii and will not be admitted to these islands under the present quarantine regulations.

Rat Abundance

Due to the rapid multiplication of rats under the favorable conditions of climate and environment in Hawaii, the number of living rats in cane fields at harvest

time is often unbelievable. In one field at Grove Farm Company on Kauai, over 2000 live rats were dug out of the ground and killed by men and dogs after the crop had been removed early in 1929. At the Lihue Plantation Co., Ltd., on Kauai, the harvesting gangs are followed by men and dogs to kill the rats. Since 1922 the Grove Farm Co. has trapped rats, for the first two years using five men steadily and thereafter using only one man throughout the year. The following table presents the facts in this instance:

Year	Number of Rats Caught	Average Number of Rats Caught per Month	Average Number Rats per Trap per Month
1922....	23,634	1,929	....
1923....	35,206	2,939	....
1924.......	8,926	744	7.44
1925	8,724	725	7.25
1926.............	8,470	705	7.05
1927.............	9 945	828	8.28
1928..	6,674	556	5.56

Average number of rats caught per month per trap for seven years, 7.11.

Since July, 1929, the number of rats caught per month has fallen off considerably due to the very thorough distribution of poison during the spring months of 1929. E. H. W. Broadbent, manager of Grove Farm Company, has made a continuous fight against rats during the past 10 years and his cooperation in the experimental use of the various poisons and new methods of distribution utilized in the recent campaign against rats has been of great benefit to all concerned.

On Kipu Plantation on Kauai during the year 1928 a total of 10,935 rats were trapped on field borders and killed in the harvest fields. Through the use of the recently developed thallium rat poison the rat population of Kipu has decreased and the percentage of rat-eaten canes coming to the mill has been decidedly reduced.

Nesting Habits

Rock piles, waste land, woodland, and any kind of shelter provide nesting places for rats. In the coffee district the lava rocks in and about the coffee plantings provide excellent hiding places, especially the stone walls surrounding the fields. The nests of the field rats in cane fields are largely under the ridges between the lines of cane as well as in stone walls and rock piles. The rats provide nesting places which will not be submerged by irrigation or excess rain. A portion of the runway is usually above the water level. Burrows may extend several feet along the line of cane. The nests are usually 6-8 inches in diameter and lined with dry grass or cane trash.

Food Habits

In rat depredations on coffee lands the rats cut off the young branches loaded with coffee, drop these to the ground and eat only part of the fruit. They thus injure more than they eat. The greatest damage is caused by the removal of the

fruiting branches. In avocado culture rats eat portions of attached fruits, thus destroying large quantities.

In cane fields the small part of the stalk usually eaten is insignificant, yet the entire stalk may die and as a result of fungus invasion, decay, and yield little or no sugar. Rats may eat practically all of one stalk or all of several in one stool. The feeding is mostly nocturnal. Once the rat has located a satisfactory mature stalk he returns successive nights to the same stool of cane, until all stalks are eaten, in part at least. Other stools near by are then selected and destroyed. This results in the lodging of the cane and finally at harvest, a great number of dead stalks which have been cut off by the rats are left in the fields. This dead cane must be destroyed by burning, or be removed from the field before starting the succeeding ratoon crop of cane. Where rat damage has been severe it has often been estimated that 10 to 12 tons of cane per acre were left on the land after harvest. In addition to the sugar loss there is also the additional expense of destroying this dead cane material to be added to the actual loss caused by rat injury. In addition a great deal of the partially rat-chewed canes has been sent to the mill. Rat-chewed cane has been shown to be often so badly injured as to yield only 50 per cent of the sugar that the same weight of healthy cane would have yielded.

The extensive investigations conducted at the Paauhau Sugar Plantation Company on the 1924 crop and reported by Elliott (4) are by far the most complete of available records of damages resulting from rat infestation of sugar cane fields. In this work 26 experiments were conducted, each of which comprised 10 acres. Elliott found that 32 per cent of the cane at harvest was partially eaten by rats. Estimating the losses of sugar at 4.50 cents per lb., it was determined that the average losses caused by the rats amounted to $33.35 per acre, or $1.04 for each 1 per cent of rat-injured cane. It was also very clearly shown that approximately two tons more of rat-injured cane was required to produce a ton of sugar than was required of healthy sound cane.

Elliott (5) conducted further tests on the 1927 crop at Paauhau Sugar Plantation Company consisting of a total of 169 experiments on rat-damaged cane. The crops of 14 fields were intensively studied. Including the stalks which were both rat-eaten and borer-damaged with those rat-eaten only, stalk counts indicated that the total averaged 13.67 per cent. The sugar lost in the rat-injured canes amounted to 17.52 per cent. These investigations were confined largely to D 1135 cane.

Recent investigations conducted by Van Zwaluwenburg during February, 1930, on rat and borer damage to cane at Paauhau Sugar Plantation Company indicated that both rat and borer damage increased rapidly after the canes were 16 months old. It was determined by actual count that the percentage of rat-eaten and borer-damaged stalks averaged 22 per cent in D 1135 cane over 17 months old.

This figure corresponds with that obtained by the writer on Kauai where counts of rat-eaten canes were made in the harvest fields. The average of these counts made in rat-infested fields was found to be 22.5 per cent. Several thousand stalks were counted in this work on six plantations.

Counts of rat-injured cane sticks or pieces of cane at the mills, reported by McCleery and Elliott for the 1930 crop, show a decrease in rat damage over counts made on previous crops. Counts were made at 29 mills by members of the staff of the department of sugar technology during the grinding of the 1930 crop.

In the report on these counts, made by McCleery under date of July 30, 1930, the approximate percentages of rat-injured canes for the four islands appear as follow:

APPROXIMATE PERCENTAGES OF RAT-INJURED STICKS OBSERVED
CROP 1930

Islands	No. of Mills Inspected	Per Cent Injured Canes
Kauai	8	1.1
Oahu	5	0.53
Maui	5	1.3
Hawaii	16	2.0

Counts made in previous years by this department have not been as comprehensive as this and comparative figures for previous years are not available.

The losses in sugar caused by rat depredations can be calculated as 0.140 per cent of total probable sugar for each 1 per cent of rat-damaged cane coming to the mill. This figure has been derived by Elliott, from cane analyses made at Paauhau Sugar Plantation Company.

Rats cannot live on sugar cane alone. There is not sufficient protein in cane to supply the animal needs. Rats must, therefore, eat insects and seeds of various plants, including those of weeds and grasses. The ready availability of such food assures the rats of a good livelihood and under such conditions rats will multiply rapidly. The knowledge that rats demand a protein diet led to the use of poisoned grain for rat bait. At Honokaa Sugar Company where a systematic scheme was developed to poison rats with prepared baits, strychnine-treated wheat was used extensively.

RAT CONTROL METHODS

The Use of Traps:

Trapping is far too expensive, and never has been successful in Hawaii in controlling rats in the cane field. Extensive trapping has been conducted continuously for several years on the plantations along the Hamakua Coast of Hawaii. Here the average number of rats caught per trap per month has never been higher than seven and has often been as low as one rat per trap per month. This condition is not due to a scarcity of rats, necessarily.

The Use of Virus:

The theory that rats can be inoculated or infected with a bacillus which will cause an epidemic of a widespread nature in the rat population of a region badly rat-infested has been advanced. On the other hand rats have been plague victims for generations and yet we have innumerable rats.

Pemberton (1), of this Station, secured direct from the Agricultural Experiment Station at Sugamo, Tokyo, Japan, on December 8, 1922, fresh cultures of the bacilli of Loeffler, Danysz and Mereshkowsky. In Japan, such viruses have

been reported as having been successfully used against rats and mice. These cultures were added to baits which were tested on caged wild rats at Honokaa but all attempts to create disease epidemics among these rats failed. Both rats and mice were fed freshly prepared cultures as well as the commercial preparations, without success. If the negative results so obtained were due to age of the cultures in question, this alone would make the use of such preparations impossible here in Hawaii. A representative of a mainland drug firm was sent out to Honokaa, bringing with him fresh cultures of rat virus and he, in cooperation with Mr. Pemberton, conducted tests on living rats without success. The work done by Mr. Pemberton is considered conclusive and since that time no further investigations have been made with any forms of rat virus in Hawaii. In spite of the publicity given to rat virus and its much-advertised control of rats, there is little foundation for the statements made regarding its successful use. The United States Biological Survey in 1925, reports the annual expenditure in the United States of $500,000 for bacterial rat viruses.

A danger from rat virus is pointed out by Dean (6) as follows:

> Severe cases of food poisoning have been traced to products arising from the growth of the rat (virus) organisms which have gotten into food products and grown there. It is probably true that these rat parasites will not attack man, but it appears that when they grow in various media outside the bodies of rats, substances are produced which are poisonous to man. Infected rats, before they die, are likely to spread the infesting organism rather generally about the neighborhood, in fact the effectiveness of this method of extermination depends on spread of the infection. As Dr. J. C. Geiger says, a cannery is a poor place to attempt the control of rats by such means.

In the most recent bulletin on rat control by Silver (7) the author points out that on account of dangers incurred in human food poisoning attributed to rat viruses, two State Boards of Health have prohibited the sale of rat viruses within the states. He reports the majority of rat virus tests, conducted by bacteriologists of the United States Department of Agriculture, to have been practically ineffective and unsatisfactory.

The Study of Rat Poisons:

A great deal of work has been done on the problem of poison rat baits. The United States Biological Survey has conducted extensive feeding tests and field trials with various poison baits for rat control during the past twenty years. Their work has pointed toward the use of strychnine, barium carbonate and more recently to red squills for the control of rats. The most recent work on squills for rat poison is that by Munch, Silver and Horn (8). Red squills consists of the dried, powdered bulbous root of squill, *Urginea maritima* (L.) Baker, also called *U. scilla* Steinheil. It is a perennial plant growing wild on the coast of southern Italy, Sicily, Sardinia and elsewhere along the Mediterranean Sea. The bulbs are pear shaped, usually from 3 to 6 inches in diameter, weigh from 300 to 2000 grams and are composed of closely overlapping fleshy scales. The bulbs are dried and ground to a fine powder. When mixed with attractive bait this material is said to be very toxic to rats but does not kill domestic animals, including poultry. Red squills is toxic to rats while white squills powder is not poisonous.

Lantz (9) of the United States Biological Survey indicates a very suitable strychnine whole wheat formula for control of prairie dogs. This formula has been adopted as a particularly good one for preparations of strychnine-wheat rat poisons and has been more recently modified for use in preparing the thallium sulfate-treated wheat. This formula, when prepared according to our modifications, provided a paste carrying the toxic substance which formed a closely adhering veneer on the seed coats of the wheat grains. This coating withstood exceedingly vigorous agitation and retained the strychnine content without appreciable loss.

The formula of Lantz with slight modifications in the formula and methods follows:

MODIFIED STRYCHNINE-WHEAT FORMULA

Procedure	Ingredients	Amount Originally Indicated by Biological Survey	Equivalent Weight In Grams or Volumes in CC's.
Dissolve by boiling 15 minutes	Laundry starch in water	1 tablespoonful ¾ pint	9.0 gms. 354.0 cc.
Add	Strychnine alkaloid	1 ounce	28.35 gms.
Add	Baking soda	1 ounce	28.35 gms.
Stir and add (Keeping hot)	Thick syrup (Corn syrup)	¼ pint	118 cc. or 175.7 gms.
Add	Glycerine	1 tablespoonful	24 gms.
Add and stir	Saccharine	1/10 ounce	2.83 gms.
Thin to proper consistency with	Hot water	(Sufficient to make a creamy paste)	
Pour and mix thoroughly with clean	Whole wheat	13 qts. = 22.75 lbs.	10328 gms.
Rinse container to remove paste with and add to wheat.	Water	(Approximately) 50 cc.	

Spread treated wheat to dry without further agitation.

Artificial heat has been most successfully used in drying these preparations. When thoroughly dry the treated grain may be roughly handled without appreciable loss of strychnine alkaloid. This point has been proved by chemical analyses of samples so prepared in which the percentage of strychnine alkaloid before shaking was 0.240 per cent; after vigorous shaking two identical samples showed 0.234 and 0.238 per cent strychnine alkaloid, respectively.

Whole wheat treated according to the above formula is found to be well covered with a shellac-like coating when viewed with the low power of the compound microscope. The crystals of insoluble strychnine alkaloid may be seen embedded firmly in this glossy paste coating. The sweetening of the preparation detracts somewhat from the exceedingly bitter taste of strychnine alkaloid preparations.

The work done on rat control in Hawaii was initiated by W. P. Naquin, manager of Honokaa Sugar Company and Pacific Sugar Mill, in 1918. At that time counts of rat-injured canes in the fields at Honokaa indicated that between 30 and 40 per cent of the stalks of cane had been damaged by rats. As pointed out by F. Muir, entomologist of this Station, in his letter to the director at the time of submitting the paper by Pemberton (1) on "The Field Rat in Hawaii and Its Control," Mr. Naquin was the first plantation manager to start an intensive campaign of rat poisoning. It was early found that commercial rat poisons then avail-

able on the market were not entirely satisfactory, were too expensive for general use and that the preparations quickly moulded when exposed during rainy weather for rat consumption in the open fields. Tests were conducted at Honokaa Sugar Company which indicated that home-made strychnine alkaloid-treated whole wheat and barium cakes were satisfactory economical poison baits for use in the fields. It was observed that the very rapid deterioration of these baits in the field necessitated some form of protection. It was Mr. Naquin who developed the paraffine-dipped paper "torpedo" for wheat distribution and the paraffin-dipped barium cakes, both of which were rainproof for a time sufficiently long to make the use of such treated baits practical.

It was Mr. Naquin's early observation from feeding tests on hundreds of caged wild rats and from field trials with poison baits, both of which were conducted at Honokaa Sugar Company, that many rats were immune to strychnine poison in the usual dosage and that other rats refused to eat the strychnine-coated grains. There was, however, a large proportion of the rat population which ate freely of the strychnine preparations and succumbed to its toxic properties. For the relatively large number of strychnine-immune rats, it was determined that barium carbonate cakes would prove toxic, provided the rats could be induced to eat them. Therefore, the Honokaa Sugar Company adopted the policy of alternating the two poisons in their thorough field distributions. Gangs of men were sent periodically through every fifth to tenth consecutive line in every field of cane, distributing either paraffin-dipped paper torpedoes of strychnine-wheat or paraffin-dipped barium cakes every few feet along the way. In this manner the entire plantation cane area was swept with poison at 30 to 60-day intervals. Both poison preparations were made on the plantation very cheaply. This system, developed at Honokaa Sugar Company, proved highly successful in reducing rat losses to a minimum. Mr. Pemberton, who went to Honokaa at the request of Mr. Naquin, cooperated in this investigation. Mr. Pemberton conducted a series of tests on 428 caged wild rats at Honokaa during 1922 and 1923. A great number of different kinds of baits and poisons were tried. Many, such as arsenic, red squills, phosphorus and cyanide were tried and regarded as unsatisfactory. The best results were obtained with strychnine alkaloid and barium carbonate.

The strychnine was used in association with whole wheat or barley. The barium was prepared as barium cake made of 1 part barium carbonate to 4 parts of wheat middlings, made into a heavy paste with the addition of water, rolled into thin layers, cut into small cakes and dried thoroughly. These cakes were then dipped in hot paraffin to waterproof the material.

Attractiveness of Bait

Much emphasis has been falsely placed on odors and flavors as attractive factors in rat bait preparation. Boulenger (10) points out that of 27 different kinds of foodstuffs, including bread, meat and fish of various kinds, vegetables, oils and fruits, ordinary bread was the most attractive both to caged rats and to rats at large. Cereals, fruits, meats and oils, in the order named were less attractive than bread. The author states:

Food faintly flavored with oils of Rhodium and Anise seed, instead of improving the bait had the contrary effect. . . .

Contrary to the statements in many books on the subject of rat destruction, meat, except tripe, and fish, even when smoked, were only accepted when no other food was available.

Stanley P. Young, of the United States Biological Survey, states, in a letter to this Experiment Station January 3, 1929, that. . . . . "the sense of smell is not as well developed in the rat as in many of our other animals. We have been unable to find any value in the use of odors to attract rats to baits. . . . . The chief odorous rat repellant is naphthalene." Highly odorous baits are not necessarily more attractive than those less odorous. Soft, odorous meat baits have proved highly attractive to ants and roaches, and have consequently proved correspondingly less attractive as rat baits. Dry cereal baits do not attract ants and are attractive to rats.

COMMERCIAL USES OF RAT POISONS

The Honokaa Sugar Company at Honokaa, Hawaii, has prepared on the plantation both a strychnine-wheat bait and barium cakes during the past seven years. At each distribution the entire plantation was covered by placing baits at frequent intervals in every fifth or tenth line of cane.

The result of this campaign has been a reduction in amount of rat-injured cane coming to the mill. The amount of rat-injured cane which prevailed before the rat campaign at Honokaa was estimated at 25 per cent of the stalks. It was less than 4 per cent at the beginning of the 1929 crop. The home manufacture of strychnine-wheat has provided the plantation with a rat bait having a strychnine content approximately 0.301 per cent, which has been somewhat higher than any of the commercial preparations at present on the market. The United States Biological Survey published in 1925 a statement to the effect that the annual expenditure for chemical rat poisons in the United States amounts to $1,380,000 and that the total annual expenditure for rat control is more than $2,000,000.

The recommended strychnine content of strychnine-coated rat baits has been set at 0.25 per cent by the United States Biological Survey, which has done a great deal of work on the subject of rat baits. Some of the commercial rat baits offered by manufacturers of strychnine-wheat rat bait analyze less than 0.25 per cent strychnine.

On Kauai, during 1928, well over 90 tons of strychnine-wheat were used by the several plantations concerned in rat control. The control obtained by the use of these large quantities of strychnine-wheat was not at all commensurate with the cost of bait and distribution. Rat injury continued and losses amounted to as much as 10 to 12 tons per acre of dead cane which was often left in the fields, in addition to the vast amount of partially eaten cane taken to the mill. Additional labor costs were incurred in either burning or removing this mass of dead cane from the harvest fields.

The milling of such partially eaten and often soured canes resulted in extremely poor juices and lowered the sugar yields considerably. These losses became so marked that J. T. Moir, Jr., manager of the Koloa Sugar Company asked to have

an investigation conducted during the summer of 1928 to determine better methods of control of the rat population on Kauai.

Rat Investigation on Kauai

A preliminary survey was made during September, 1928, and rat feeding tests were begun on wild rats retained captive in screen cages at Koloa Sugar Company. Tests were conducted to determine the toxic value of the packages of strychnine-wheat, called "torpedoes," which were being distributed in the cane fields at that time. These packages containing one heaping teaspoonful of wheat each, were wrapped in single sheets of toilet paper and dipped in melted paraffin to make them waterproof.

It was early determined that rats preferred to eat the packaged wheat that had not been dipped in paraffin, rather than the dipped torpedoes. It was also soon discovered that the undipped packages were more poisonous than the dipped packages. Rats which were fed torpedoes of strychnine-wheat which had not been dipped in paraffin often died after eating a single such torpedo. Similar rats were able to eat several dipped torpedoes before dying and the time interval before death was often two or three times as great as for the rats fed undipped torpedoes.

The cause was found to be partially due to the fact that the paraffin had penetrated the thin tissue paper package and coated the wheat grains as well as the paper. Since the rat ate the grains without removing the wax from the seed coats, the coating of strychnine on the seed coat was sealed over with wax, and, since paraffin wax is indigestible, the strychnine layer beneath the wax coating was held in an indigestible matrix. This condition thus made the poison value of these packages very low, since such a small portion of the wheat was free of paraffin. It was found that only 25 per cent of the wheat in such torpedoes was free of paraffin.

In addition to this indigestible feature of the strychnine coating on the grain contained in such waxed torpedoes, the results of analyses made by the chemistry department of the Experiment Station showed that the strychnine content of much of the strychnine-wheat then being used ran as low as 0.14 per cent. This condition was found to be due to the non-adherence of the applied strychnine alkaloid, which, being insoluble in water, was made to adhere to the grains through the use of a cold starch paste. It was also found that starch which had been boiled for 15 minutes in order to break down the starch grains became extremely adhesive. Strychnine alkaloid could not be easily removed from wheat grains which had been treated with a paste composed of the drug mixed in a boiled starch paste. It was found that such preparations should be dried without agitation by artificial heat. Through the adoption of these changes the strychnine content of the rat bait soon rose to 0.25 per cent. The large amount of analytical work done by Fred Hansson, of the chemistry department of the Experiment Station, involved the strychnine analysis of 67 separate samples.

Observance of Rat Immunity to Strychnine

Subsequent to this change in the mode of preparing strychnine-wheat rat bait, it was found that certain rats were able to consume large quantities of strychnine-

wheat without suffering any discomfort whatever. Fifty-four torpedoes of strychnine-wheat were fed to one black rat retained in a screen cage. All were eaten by the rat during the 59 days in captivity. He finally died after eating a portion of a barium cake. The Honokaa Sugar Company reports having fed one black rat with strychnine-wheat torpedoes only for six months. In the following table are the strychnine-wheat-consumption records of 114 rats many of which finally died subsequent to eating single barium cakes or parts thereof.

Number of Rats	Number of Strychnine-Wheat Torpedoes Eaten by Each Rat	Number of Days in Test Before Death
1	35	42
1	13	14
1	11	14
1	10	11
3	8 each	(Average) 16 each
1	6	(Average) 16
10	5 each	..
12	4 each	..
27	3 each	..
57	2 each	..

At all times caged rats were provided daily with fresh-cut sugar cane, and water in tin containers. To the rats which were found to be immune to strychnine poison we fed barium cakes, but it was soon found that it was necessary to deprive these rats of all other forms of food before they would eat even a small portion of the barium cakes. Whenever such rats ate even small fragments of barium cake, death resulted in a short time.

Cage Tests With Strychnine Wheat

In the cage tests conducted on Kauai with rat poisons of various kinds a total of 483 wild rats and mice were used. Of these a total of 12 rats escaped by chewing at the sides of the box until they were free. A total of 60 rats died of injuries received in trapping or catching them or from natural causes. Poison tests were therefore completed on 411 wild rodents. The rats used in the test were classified as follows:

Species	Number
Rattus norvegicus	327
Rattus rattus	21
Rattus alexandrinus	96
Mus musculus (mice)	7
Undetermined	2
Total	453

During the testing period several kinds of poison baits were used. The number of rats dying from ingestion of the separate poisons are as follows:

Rats poisoned with strychnine	212
Rats poisoned with barium	75
Rats poisoned with thallium	124
Total number of rats poisoned	411

Each rat was given a serial number when caged and was placed in a clean, screened box in which was placed a can of water, several pieces of split sugar cane and one or more torpedoes of the poison preparation under test. Rats numbered 1 to 240 were fed strychnine, which was often followed by barium. The average toxic dose of commercial strychnine-wheat for these rats was 2.5 torpedoes and the average life of the rats was 5.6 days.

In the tests conducted with strychnine-wheat prepared by the United States Biological Survey formula 82 rats were tested. The average number of torpedoes eaten by these rats was 1.4 and the rats lived an average of 5.4 days before the poison proved toxic. Tests were conducted with the commercial strychnine-wheat prepared by the local factory. Torpedoes were made of two kinds of paper. The cheap toilet paper, paraffin-dipped torpedoes were less toxic than torpedoes of the same size and of the same material prepared of a thin white parchment paper called "Fibrespun Bond" which did not allow the melted paraffin to penetrate the paper. The results were as follow:

COMPARISON OF EFFICIENCY OF PARAFFIN-DIPPED TORPEDOES

Kinds of Paper Used for Torpedo	Average Number of Torpedoes Eaten per Rat	Average Life of Rats During Test
Shasta Toilet Paper.........	3	8 days
Fibrespun Bond Paper.... .	1.6	3.4 days

In the search for better adhesive materials for causing adhesion of the strychnine crystals to the seed coats of the grains ordinary glue was used. Carpenter's white fish glue was added in place of starch, using 0.78 per cent by weight. This poison preparation was fed to 18 wild rats, in this instance having the torpedoes prepared from wax paper, not dipped in paraffin. The average number of torpedoes eaten by these rats was 1.3, and the average elapsed time before death of the rats was observed was 4 days. This preparation was by far the most rapid and effective rat bait prepared from strychnine and wheat. The glue was probably more rapidly digested in the gastric juices than the starch paste adhesive material usually used.

The tests conducted with a commercial strychnine-wheat bait produced on the mainland were limited to 7 rats. Six of these rats ate an average of two torpedoes each and lived an average of 7 days under test. One rat ate 12 torpedoes and finally died after eating one thallium sulphate-wheat torpedo.

The tests conducted with the home-made strychnine-wheat prepared by the McBryde Sugar Company, Limited, were made on 21 wild rats. These rats ate an average of 1.5 torpedoes and survived only 3 days. This preparation was made on the plantation by using 5 ozs. of strychnine to each 100 lbs. of crushed barley. This concentration was slightly higher than has been usually used.

CAGE TESTS WITH BARIUM CARBONATE PREPARATIONS

Barium-coated wheat was tried but the caged rats hesitated several days before eating such bait. A barrel of wheat was treated with 2 per cent barium carbonate, using the adhesive materials as recommended in the United States Biological Sur-

vey formula for strychnine-wheat to serve as a binder for the poison. Field tests were conducted on several plantations but without success. Rats at large did not eat freely of these torpedoes. Feeding tests on caged rats were conducted on 12 wild rats at Koloa. These 12 rats ate 16.4 torpedoes prepared with this material wrapped in "Fibrespun Bond" paper and dipped in paraffin. They lived a total of 97 days. The average toxic dose was 1 3 torpedoes and the average length of time the rats were under test was 8 days before death was observed. Barium carbonate was mixed with dry ground meat scraps but rats refused to eat these preparations. Melted cheese scraps obtained from the Atlas Warehouse and Cold Storage Company, Green Bay, Wisconsin, were tested as a bait with which 20 per cent of barium carbonate was thoroughly mixed. Such bait was made up into small 12-15 gram paper packages or torpedoes which were fed to caged rats. None of this material was eaten by the rats. Pre-baiting with cheese torpedoes free of poison was tried. The rats did not relish the cheese. Such baits were extremely attractive to ants, however.

Canned fish, too soft for ordinary trade purposes, was tried as a bait mixed with barium carbonate. Rats did not relish this preparation. Ants always found the packages in the fields and quickly ate the fish contents.

No case was observed wherein any rat even nibbled of a barium cake until all other food had been previously removed from the cage. This preparation was apparently very distasteful to rats. It was observed that most rats dying from barium poison were found in or near the water container within the cage. No cake was entirely eaten by rats; lethal results were produced by ingestion of only slight fragments. The marked dislike for preparations containing barium carbonate was a general observation of all tests with this preparation.

The strychnine-wheat prepared according to the United States Biological Survey formula proved far more toxic than the bait previously used, yet it did not kill those rats that were immune to strychnine. The McBryde Sugar Company, Ltd., at Eleele, Kauai, cooperated in feeding tests of poison baits. Keith Tester, former agriculturist for that plantation, conducted a large number of tests with various poisons placed in feeding shelters in the fields where the rats were free to come and go. His tests in part are summarized in the following table:

Preparation of Bait	Average Percentage Removed
Strychnine barley and fish (wet)	95
Corn meal, barium and fish (wet)	51
Strychnine barley (dry)	100
Corn meal and barium carbonate (dry)	0

At the stations where fish preparations were fed the ants and cockroaches were big factors in removing the bait. Feeding shelters are well adapted for easily accessible rock piles and along stone walls but for general field distribution of rat baits, the expense of preparing shelters of wood and roofing paper plus the cost of placing them in the field and recovering them later does not seem warranted.

Torpedo distribution of poison in attractive paper packets has proved cheaper and equally effective.

Strychnine barley with and without animal fat added was fed in shelters to wild rats in the field. Very slight preference was shown for the grain treated with

fat. It was observed also that ants prevailed wherever fat-covered wheat was exposed. This condition made such baits less attractive than the fat-free baits.

Mr. Tester's feeding of wild caged rats with strychnine baits and barium baits supported all the tests carried on at Koloa Sugar Company by the writer. The cooperation of the McBryde Sugar Company and of Mr. Tester has been greatly appreciated in this project.

A summarized table follows in which all the tests conducted on Kauai with the various forms of strychnine-wheat and barium carbonate preparations are listed.

Poison Bait Fed to Caged Rats	Number of Rats Tested	Average number of Torpedoes Eaten	Average Number of Days Rat Survived
*Commercial strychnine wheat (Old formula)	85	1.8	4.0
Strychnine wheat (Biological Survey formula)	82	1.4	5.4
McBryde Sugar Co., strychnine barley	21	1.5	3.0
Makee Sugar Co., commercial strychnine wheat	6	2.0	7.0
Strychnine wheat with glue......	18	1.3	4.0
Whole wheat plus 2% barium carbonate	12	1.3	8.0
†Barium mixtures after strychnine wheat torpedoes	52	Strychnine 2.1 Barium 1.2	7.0
Barium mixtures only............	11	Variable	8.0
Total..................	287 rats		Average 5.2 days

A search was made for a poison that would replace strychnine and yet not be too expensive. Such a poison was found and developed during this work.

Tests With Thallium Sulfate

Trials were conducted during March, 1929, with the first thallium-treated wheat preparations to be used in Hawaii. The thallium sulfate was used at the rate of 1 lb. to 1000 lbs. of whole wheat and the results obtained in cage tests were very satisfactory. All caged wild rats subsequently fed thallium-treated wheat died from the poisonous effect of this highly toxic salt, even in these small quantities. Increasing the amount of poison to one pound of thallium sulfate for each 750 lbs. of whole wheat gave no better results than were obtained with the weaker concentration. The content of the package or torpedo was maintained at one teaspoonful of the treated wheat, which permitted the preparation of 45 to 50 torpedoes per pound of dry rat bait.

A total of 124 wild rats, held captive in cages, was fed thallium-treated wheat. An average of one torpedo was eaten by each rat and the average life of the rat

* Commercial strychnine wheat prepared according to our old formula at the factory in Honolulu has been used extensively for the last few years.

† These tests were often started with several kinds of strychnine-wheat preparations and one or more forms of barium preparations placed before the caged rat in order to determine rat preferences for such baits. In other cases the barium was given after several strychnine-wheat torpedoes had been eaten without lethal results.

after feeding this preparation was 3 days. All rats to which this poison has been fed in cages have eaten the preparation. No rat refused to eat the preparation in these tests.

The tests conducted on caged wild rats were limited in numbers of individuals used principally because of the difficulty in trapping wild rats. The symptoms of thallium poisoning on rats under observation were extremely easy to detect. Within 24 hours after eating thallium baits the rats appeared to be blind, were extremely inactive and were unable to control the muscles of the hind legs. All rats poisoned by thallium exhibited extreme cases of cataract of the eyes, and the eyes were watery at death. A summarized table of results of our feeding tests in cages follows:

No. of Rats Tested	Ratio of Thallium Sulfate to Wheat	No. of Torpedoes Eaten by the Group	No. of Days Elapsed Before Death Was Observed	Average No. of Days per Rat
6	1-1000	7.5	20	3.3
37	1 1000	41.2	114	3.0
45	1-750	38.0	132	2.8
14	1-1000	16.0	33	2.3
16	1-750	16.0	45	2.8
6	1 1000	6.0	39	6.5
Total 124 rats		124.7 torpedoes	383 days	

Average number torpedoes eaten per rat............1.0
Average number of days rat lived...... .... 3.0

At McBryde Sugar Company, Limited, Mr. Tester fed 16 caged wild rats each one torpedo of thallium-treated wheat (1-1000 concentration). The single torpedo was toxic in each case and the average life of the rats in the cages was 2.3 days.

The observed difference in time required for toxic results with the higher concentration of the poison indicated that the stronger dose acted the quickest. But inasmuch as all rats which were fed thallium preparations died in due time the value of the lower concentration is fully justified. It is also more economical to prepare and is apparently equally as effectual as the higher concentration of poison.

The thallium-treated wheat was the most readily taken of all the baits tested and caused the death of the individual rats in the shortest observed time. Furthermore, a lesser quantity of the poison bait was required to kill the rats than was needed for any other preparation tested.

The work done by Munch (11) on thallium poisoning is the most recent on this subject. He found that the minimum lethal dose (M. L. D.) for rats was 25 milligrams of thallium per 1000 grams of body weight. When intravenously injected into rabbits the M.L.D. is the same. He states that: " . . . . although thallium sulfate is occasionally given to children (medically) in doses of 8 mg. per kilogram of body weight, it has caused toxic reactions even in doses half that size. Thallium affects the sympathetic nervous system, thereby causing alopecia, pains in the muscles and nerves of the legs, and disturbances of the endocrine glands, particularly the ovaries or testicles. Thallium is cumulative in action; tolerance

does not develop in animals. Thallium is a certain, but not a rapid, poison for rats."

The average weight of an adult gray rat is approximately 325 grams. Therefore the M.L.D. for such rats would be 8.3 milligrams of thallium. Torpedoes prepared from the 1 to 1000 concentration of thallium sulfate-treated wheat which contain not more than 10 to 12 grams of bait would therefore carry a slightly excessive dose of thallium which would insure toxic results when eaten entire by a single rat. Such torpedoes can be prepared by making 45 packets per pound of treated wheat, each containing approximately 10 grams of grain. Larger torpedoes are wasteful, especially if the grains are free of paraffin, which may penetrate the lighter, more porous tissue paper wrappers. Tough non-porous paper is, therefore, best for preparing torpedoes of rat bait.

At the present time all plantations in Hawaii using rat poison in large quantities are using thallium-treated wheat exclusively. Where this poison has been thoroughly distributed in badly rat-infested cane areas the heavy feeding of rats has practically ceased within a week after such distribution. A second distribution of this preparation has usually eliminated the rat population of such areas.

The formula adopted in Hawaii for preparing thallium sulfate-treated wheat is simply a slight modification of the strychnine-wheat formula appearing under the heading "The Study of Rat Poisons." The substitution of thallium sulfate for strychnine alkaloid necessitated a few changes in technique and in equipment.

Iron or copper containers should *never be used* for preparing solutions of thallium sulfate. Glass, porcelain or lead containers only should be used to avoid decomposition of the thallium sulfate. Boiling the solution for any length of time should be strictly avoided as well. At such temperatures the decrepitation (or tendency to "splatter") of the solution makes handling of the preparation dangerous. The starch, however, must be boiled for 15 minutes in order to break down the starch grains. The non-poisonous ingredients may then be added to the boiling starch paste and thoroughly mixed. In conclusion the thallium sulfate may be dissolved in sufficient hot water and mixed thoroughly with the paste preparation. Proportionate parts of the paste preparation are then removed and poured over equivalent amounts of clean whole wheat and thoroughly mixed. The wetted grain is then spread to dry, preferably in the presence of artificial heat, in order to prevent moulding under unfavorable conditions of air-drying.

The following formula is the one at present successfully being used in the preparation of thallium sulfate-treated wheat for rat bait. No operators should attempt to prepare large quantities of this preparation without the *protection of rubber gloves.*

MODIFIED THALLIUM SULFATE-WHEAT FORMULA

Ingredients	Small Lot, Amounts	Amounts in Grams or CC's	Ton Lot, Amounts	Procedure
Starch	1 tablespoonful	9.0 gms.	2.0 lbs.	
Water	¾ pt.	354.0 cc.	6.8 gals.	Add and boil for 15 minutes.
Baking soda	1 ounce	28.35 gms.	5.5 lbs.	Stir and boil.
Thick syrup	¼ pt.	118 cc. = 175.7 gms.	2.3 gals.	Stir and boil.
Glycerine	1 tablespoonful	24 gms.	4.6 lbs.	Stir.
Saccharine	1/10 ounce	2.83 gms.	8 oz.	Stir.
Thallium sulfate	(in warm water)	10.328 gms.	2 lbs.	First dissolve in hot water. Mix thoroughly after adding to paste.
Whole wheat	13 qts. or 22¾ lbs.	10328 gms.	2000 lbs.	Paste is added to small lots in proportionate amounts and thoroughly mixed.

Treated grain to be spread immediately for drying.

CAUTION: Do not allow this solution or paste to come in contact with the skin until after drying.

HISTORY, SOURCE AND USES OF THALLIUM

Thallium, one of the rare elements, was discovered by Crookes in 1863. The name, thallium, means green, due to the formation of a green line in the spectrum. Thallium burns with a green flame. The element occurs in various ores which also contain sulphur. The chemical symbol is Tl; the atomic weight is 204.0.

Most of the commercial thallium sulfate used today comes from Germany. It is a by-product of smelters. The form used is the thallous sulfate, which is more stable than the thallic form. During the past two years a great deal of thallium sulfate has been used in California in control of ground squirrels, but the amount of thallium sulphate used per ton of wheat has been 10 times as much as we are using per ton of wheat prepared for rat bait.

Due to a monopoly of the product, the imported chemical sells at a price which varies from $11.00 to $15.00 per pound. Even though this price seems high, the small amount needed to prepare a ton of wheat, i.e., 2 lbs., is not as costly as the usual amount of strychnine alkaloid used per ton of wheat. There is a saving of at least $20.00 per ton for poison material used.

THALLIUM AS A DRUG

This drug was formerly used therapeutically in cases of night sweats of phthisis. It has been extensively used as a depilatory agent. The therapeutic use of thallium has been discontinued on account of the severe cases of human poisoning which have resulted. A great deal of work has been done by German and French investigators on the subject of thallium as a drug and as a poison. The symptoms of thallium poisoning are summarized by Munch (11) in his reference to the work of Kaps (12) as follows: "A short period of excessive gastro-intestinal pain, emesis, nausea, colic and diarrhea which soon changes to obstinate constipation; disorders of the central and vegetative nervous systems; degeneration of the heart, liver and kidneys."

The symptoms of thallium poisoning are somewhat similar to those of lead poisoning, although distinguishable. General symptoms are reduction in vision, cataract, nephritis, alopecia, and endocrine disturbances of various sorts. The discontinuance of thallium as a medicine is certainly warranted.

Toxicity of Thallium Baits to Other Animals

Thallium-treated wheat has been held responsible for the death of poultry, turkeys, and horses during the past year. Whenever such rat baits are to be placed close to camps or poultry runs where the fowls are allowed ordinarily to run at large, the fowls should either be penned up during the time the poison is distributed or at least until the rats have taken the poison. Horses have been allowed access to bags of thallium-wheat and have died from eating the torpedoes.

Where poultry have plenty of available food at all times there is less danger of their taking thallium-wheat baits in torpedoes.

Tests were conducted on two young roosters in which they were fed thallium-treated wheat. Five torpedoes were taken by each chicken in the course of 26 days without any symptoms of poisoning during that time. Only one torpedo was offered to each rooster on any one day of the test. Had they not been able to get plenty of other grain the results might have been different. These torpedoes were purposely opened for the chickens at time of feeding. Three white rats were caged and fed one torpedo each. Within three days all rats were dead. The torpedoes were all from the same lot.

Tests were conducted on Chinese pheasants in relation to the toxicity of thallium sulfate-treated wheat torpedoes through the cooperation of J. M. Kelly, chief fish and game warden of the Territory of Hawaii. Torpedoes were sent to the Territorial Game Farm where tests were conducted by Irwin H. Wilson. Two adult pheasants and two two-month old pheasants were penned and fed thallium-wheat torpedoes unopened. These were not touched by the birds during 48 hours. Other torpedoes were opened and placed in the cages with other grain feed. The pheasants lived 13 days during which time only slight amounts of poisoned grain were eaten. No birds became ill. Six wild rats were caged and fed three similar thallium-wheat torpedoes. Within two days after caging and feeding the rats were dead.

Antidotes for Thallium Poisoning

Very little is known relative to specific antidotes for thallium. The Bayer Company who market a thallium paste preparation known as "Zelio," which they recommend very highly for domestic rat control, states as follows: "Antidote: Call a physician. While waiting, induce vomiting by inserting the finger in the back of the throat. Give an emetic, such as mustard or salt dissolved in warm water. Follow vomiting with Epsom or Glauber salts."

Braun-Knecht-Heimann Company, manufacturing chemists of San Francisco, recommend the following antidote: "Give large dose of Epsom salts in solution of water. Empty stomach as soon as possible by use of stomach tube or emetics."

Buschke, Duchan and Joseph, (13) have investigated the value of sodium thiosulfate as an antidote against thallium poisoning. Mice fed sodium thiosulfate

for 14 days consecutively died within 2 or 3 days after being given subcutaneously a known lethal dose of thallium sulfate.

Where the sodium thiosulfate was given to mice by injection for 14 days prior to injection of known lethal doses of thallium acetate, the mice died within 2 or 3 days Several mice given simultaneous injections of both thallium acetate and sodium thiosulfate remained alive. One mouse weighing 21 grams, having received 1.4 mgs of the thallium, died.

Fifteen rats were treated in a similar manner with parallel results The authors feel that there is no certain basis for using sodium thiosulfate as an antidote.

Buschke (14) states that experiments conducted by himself and Dr. Joseph have been negative up to December, 1928. He points out that the therapeutic action of thallium is not lessened by ministrations of sodium thiosulfate. In Russia a great spread of a fungous disease of the hair has brought about recently the use of thallium salts in medical control The use of sodium thiosulfate to prevent acute cases of thallium poisoning has been studied by Mrongowius and Duchan (15). Sodium thiosulfate ($Na_2S_2O_3$) has been shown by others to be an antidote for arsenic, mercury and thallium. Experiments conducted on children from 12 to 18 years of age, who were patients at the hospital for skin diseases, indicated that symptoms of thallium poisoning following thallium acetate doses were absent when the patients were given, per orum, 1 to 1.5 gms. of sodium thiosulfate daily. Symptoms of poisoning vanished when sodium thiosulfate antidotes were given for four successive days. Further tests were not conducted. There seems to be evidence to show that in cases of slight poisoning with thallium salts alleviation of pain can be obtained in human beings with 1 to 1.5 gram doses of sodium thiosulfate dissolved in water and taken internally.

Dangers Involved in Handling Thallium

Thallium is very poisonous to man and though it was once used as a drug, this practice has been discontinued on account of the ill effects observed in medical practice.

When in aqueous solution, thallium sulfate is readily absorbed through the skin and is especially dangerous when handled continuously. Such contacts often result in lameness, and falling of the hair. After a time the hair usually is replaced with a new growth.

For those who are handling this poison in an aqueous solution, the use of rubber gloves is recommended. For those who handle the dry thallium-treated wheat, frequent washing of the hands and as little skin contact with the poison-coated grain as possible, is recommended. Frequent washing of the hands and thorough drying are essential to safety in handling this preparation.

The Packaging of Rat Baits

Several kinds of paper are at present used for making rat bait torpedoes. The cheap flat sheets of toilet paper so much used give better service where two sheets are used for each torpedo. There is less penetration of the hot wax through the two sheets of paper. The paraffin should be kept constantly at a temperature

slightly above 120° C. during the dipping process. The torpedoes are held in the hands of the operator by the twisted tops and simply immersed momentarily in the hot wax and after draining for a short time are allowed to cool on large trays. When cool the torpedoes are put into bags for field distribution. Heating of the wax may be secured by the use of a kerosene heater or an electric plate.

A better grade of thin white paper has been successfully used for the preparation of torpedoes There is little penetration of the hot paraffin through this better grade of paper and though the paper may cost a little more than the thin toilet paper sheets there is less absorption of paraffin and consequently less cost for paraffin used in the dipping process.

The white paper torpedoes have the advantage of greater visibility in the cane field than have the brown tissue paper dipped torpedoes This is an advantage to both rats and man. The paraffin coating is primarily made as a protection against rain.

In a torpedo which has not been dipped in paraffin the wheat will become mouldy very quickly during or after a rain. Such mouldy grain will not be eaten by rats. Where rainfall is of very rare occurrence, waxed paper sheets are satisfactorily used for making torpedoes. These need not be dipped in hot wax.

Ordinary glassine paper is sometimes used for torpedo-making but a slight shower will cause these torpedoes to become untwisted and later allow rain to reach the wrapped grain. Mould will soon overgrow such packages of grain. The size of the sheets of paper used in making torpedoes varies with the grade of paper used. A sheet of paper 5 x 5 inches makes a very suitable torpedo. The size is usually determined by the most advantageous cutting of the large sheets of stock paper. These sheets usually measure 22 x 36 inches and can be cut without waste into 28 smaller sheets of uniform size.

For convenience and speed in preparing torpedoes a "shaper" has been devised. This device consists of a 1 by 10 inch cylinder of wood attached in a vertical position on a board platform. The upper end of the cylinder should be rounded off to form a hemispherical top. The sheets of paper to be shaped are placed singly directly over the rounded top and shaped down over the cylinder quickly with the other hand of the operator. This produces a cup-shaped receptacle into which the measured dose of rat bait is poured and the paper then twisted to form the torpedo. One operator can usually shape enough single paper "cups" for several workers to fill and finish.

Field Distribution of Rat Bait

Rat bait should be placed near the feeding places of rats. Heavy distribution of baits should be around rock piles in which many rats are living. As long as the applied torpedoes are all eaten the indications are that more rats may be present. Repeated distribution of poison should be made within two weeks after the first application provided indications are present that rats are still feeding on cane in that particular field or region. Irrigators, carrying small bags of torpedoes, often aid in poison distribution by dropping torpedoes where necessary.

Frequent inspection of the interior parts of the cane fields should be made and on finding fresh evidences of rat feeding, poison should be distributed thoroughly, leaving at least one torpedo close by each stool of cane found to be recently partially eaten. Recent feeding can be determined by the light color of the freshly chewed sections of stalk. With age the partially chewed regions on the stalks take on a darker color. This is due to oxidation and the attacks of various organisms, including bacteria, yeasts and fungi.

Rats prefer fairly mature cane which has a fair sugar content. They will not feed on very young plant or ratoon growth. Mature cane fields are the usual haunts of field rats. When the harvesting has been completed the rats which occupied the cane areas are forced to migrate to other suitable-aged canes for food supplies. This is a very logical time to apply poison in the fields to which the rats move, because the young cane in such fields will usually be upright and can be easily inspected and poison applied.

Even in cases of extremely heavy rat infestation, where thorough poison distribution has been made, very few, if any, dead rats will be found. Rats poisoned by thallium retreat to the darkest corners before dying. The best indication of the efficiency of this poison is the cessation of fresh injuries on growing canes.

Poison application on any plantation should be in the hands of one individual who will have charge of the distribution of poison where needed. Rat poison distribution on a sugar plantation should be a year-round process and will under such conditions very rapidly reduce rat damage to a minimum.

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Summary

1. Previous investigations on rat control in Hawaii and elsewhere are reviewed.

2. Rats in Hawaii are limited to three species: *Rattus norvegicus*, *R. rattus* and *R. rattus alexandrinus*.

3. Partial control of rats is obtained in Hawaii through the activities of the mongoose.

4. Recent investigations have shown that many rats are immune to strychnine poison.

5. Barium carbonate preparations are not attractive to rats, although very toxic even in small doses.

6. A modified formula for preparing strychnine alkaloid-treated wheat is presented. A glue-strychnine-wheat formula which proved effective is also mentioned.

7. Investigations have shown that one pound of thallium sulfate per 1000 lbs. of whole wheat makes a satisfactory rat bait. A formula for preparation is presented.

8. Thallium-treated wheat in these concentrations was toxic to all rats tested.

9. One 10-gram portion of such preparation is a lethal dose for an adult rat.

10. Such portions, wrapped in paper torpedoes and dipped in melted paraffin make excellent waterproof packages for field distribution.

11. Wherever such torpedoes of thallium-treated wheat are adequately distributed in rat-infested regions satisfactory lethal results have been obtained.

12. This rat bait has been adopted for regular plantation practice to control the rat popula ion in Hawaii. Success has attended its use.

13. Antidotes are not well known, but sodium thiosulfate has been recommended.

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Cane Growth Studies at Waipio Substation

EXPERIMENT E

BY ARTHUR AYRES

At the time the 1929 issue of the *Reports of the Association of Hawaiian Sugar Technologists* went to print, while the harvesting of this experiment was complete, the chemical analyses of the samples taken were not. Hence, only a preliminary report, under the above title, by G. R. Stewart and J. A. Verret, was included in that issue.

The harvest data as presented by them (corrected to cover certain errors in calculation pertaining to final extraction of water from the samples that found their way into the above-mentioned paper) plus the analytical results of the last three harvests, recently completed, form the basis of this paper.

No attempt will be made in the present paper to thoroughly interpret the data presented herein. This article will constitute, rather, a brief outline of the experiment, with frequent references to the preliminary report, followed by a somewhat varied presentation of the analytical, in conjunction with the harvest data, and such observations by the writer as may seem appropriate.

Referring to Messrs. Stewart and Verret's article for a description of the experiment:

> This experiment was originally planned and laid out by the agricultural department for the purpose of studying the yield of cane and sugar given by the H 109 variety when planted at different periods of the year. The chemical department was given the opportunity of studying the mineral composition of the cane harvested in these growth studies. . . .
>
> The scheme of the experiment as laid out by the agriculturists was to harvest a series of five plots of cane of graduated age, at equal growth periods, throughout a space of time equal to thirty growth months. At the first period of harvest the planting of the cane had been so adjusted that the cane on the five plots had grown for periods of time equivalent to three growth months, six growth months, nine growth months and twelve growth months. In addition, the weight and composition of the seed cane which would have been employed on one plot were likewise determined. At the second period of harvest the cane was aged three growth months, six growth months, nine growth months, twelve growth months, and fifteen growth months. At each successive time of cropping the youngest plot taken off was three growth months older than at the preceding harvest. It should be clearly understood that the calendar months between each harvesting period were in some cases longer than three months, and in other cases shorter than three calendar months.

The last sentence is confusing. Probably the authors meant "growth months" instead of "calendar months" where the latter term first appears in the sentence. In some instances, in the older plots, there were considerable quantities of dead cane. Where this was the case, samples were selected for analysis. Each plot comprised 1/40 of an acre.

The yield data for millable cane, tops and leaves, trash, and dead cane, on both a fresh and a dry basis are presented in Table I. The yield of sugar is included in this table. These results have all been calculated to an acreage basis. The data are presented graphically in Figs. 1 and 2.

The graphs included in this paper have been worked out on the same principle as those in the report by Messrs. Stewart and Verret. Again referring to their paper:

> In preparing those graphs each crop has been followed through its growth at each successive period of harvest. Thus crop No. 1 is the crop which was seed cane at the period of the first harvest. This crop was three months old at the second harvest, and so on up to eighteen months at the final harvesting date for this crop. Crop No. 2 represents the plot which was three months old at the first date of harvest, and finally reached an age of twenty one months at the last cropping date. This method of grouping the yield from the different plots appeared to be more logical than simply to group all the plots together which had the same age at the time of cutting.
>
> The fertilization of all the plots was carried out on the following plan: Four weeks after planting, each plot received an application of Waipio complete fertilizer containing 10 per cent nitrogen (N), 7 per cent phosphate (P_2O_5), and 7 per cent potash as K_2O, at the rate of 1000 pounds per acre. Six weeks later, or ten weeks after planting, each plot was given a fertilization with ammonium sulphate, at the rate of 585 pounds per acre. The fertilization was completed by applying ammonium sulphate, twelve weeks later, at the rate of 488 pounds per acre. The total nutrients supplied by this scheme consisted of 323 pounds of nitrogen, 70 pounds of P_2O_5, and 70 pounds K_2O per acre.

The chemical composition of the millable cane, tops and leaves, trash, and dead cane, on a water free basis, is given in Tables IIa, IIb, IIc and IId, respectively.

The number of pounds, per acre, of potash taken up by the stalks and by the entire plant, less roots, for all five crops, is presented graphically in Fig. 3. Values for the latter include the nutrients found in the accompanying trash and dead cane. Corresponding comparisons for phosphate and nitrogen are given in Figs. 4 and 5, respectively. It is of interest to note in these three graphs that the phosphate content of the stalks rises notably during the last three months prior to harvest. This is also true of potash, with one exception, whereas, the nitrogen content drops, during the same period, in every case. In order to show, in a somewhat simpler form, the relationship between the potash, phosphate and nitrogen requirements of the cane plant, less roots, the amounts of these nutrients taken up have been averaged, according to the age of the plant, and presented graphically in Fig. 6. The curve for potash, in this figure, brings forcibly to notice the tremendous demand made upon the soil for this nutrient, running in the oldest crop to well over 800 pounds per acre. This demand is very insistent in the early stages of growth, the plant absorbing nearly 160 pounds per acre between the ages of three and six growth months. The demand for nitrogen after twelve months is nearly constant, whereas, that for potash and phosphate increases constantly and, at certain ages, very sharply. In Fig. 7 is shown the relationship between the amounts of magnesia, lime and silica taken up by the millable cane of the various crops.

In Fig. 8 a comparison is made of the amounts per acre of six different nutrients taken up by the whole plant, less roots. Here again the curves represent the average values for the various crops. The demand made upon the soil for

phosphate, nitrogen and lime appears quite moderate when compared with that for potash.

Since the yield of cane and sugar varies appreciably with the different crops, a basis for comparing the mineral nutrients extracted by them was worked out on a per ton sugar basis. Figs. 9 and 10 show graphically the amounts of phosphate, potash and nitrogen per ton sugar, found in the millable cane of all five crops. Information of this nature may prove of value as an aid in determining the most economical time for harvesting from the standpoint of the mineral nutrients contained in the cane.

Summary

While the amounts of mineral nutrients absorbed by the crop cannot be used as an absolute measure of its fertilizer requirements, the curves showing the quantities of nutrients taken up, indicate the insistent demand of the plant for phosphate, nitrogen and especially potash, during the early stages of growth.

Comparing the oldest completely fertilized crops in the periodic harvesting study at Oahu Sugar Company, Ltd. (reported in *Reports of the Association of Hawaiian Sugar Technologists,* 1929), with the average of crops of equal age in this experiment, we find the potash taken up per acre by the whole plant, less roots, in these two studies to be practically identical. The crops at Oahu Sugar Company, Ltd., took up a much larger amount of nitrogen and an appreciably smaller amount of phosphate than corresponding crops at Waipio. It is felt that much valuable information could be obtained by a thorough and intelligent comparison of these two experiments.

(*Note:* The words "less roots" should appear in the explanations on Figs. 3, 4, 5, 6, 8.)

TABLE I

Periodic Harvesting Results, Experiment E, Waipi Substation

Results Expressed as Tons and as Pounds per Acre—Each Plot 1/40 Acre

Date of Harvest	Age	Crop No.	Cane Stalks, Fresh, Tons	Cane Stalks, Dry, Tons	Cane Stalks, Dry, Pounds	Tops, Fresh, Tons	Tops, Dry, Tons	Tops, Dry, Pounds	Trash, Fresh, Tons	Trash, Dry, Tons	Trash, Dry, Pounds	Dead Cane, Fresh, Tons	Dead Cane, Dry, Tons	Dead Cane, Dry, Pounds	Tons Sugar per Acre
/28	Seed Cane	1	2.67	.57	1,140	.....	.....	....	.....	....	.....	....	.....	.....	.....
	3 months	2	.....	....	.....	2.62	.397	793	..	....	.....	....	.....	.....	....
	6 months	3	11.09	1.96	3,920	19.28	3.244	6,488	..	....	.....	....	.....	.....	.47
	9 months	4	23.51	4.73	9,464	17.86	3.177	6,354	75	.306	2,612	....	.....	.....	1.66
	12 months	5	54.83	12.35	24,700	23.06	4.581	9,162	54	.732	5,464	....	.....	.....	6.03
/28	3 months	1	.....	....	.....	2.96	.658	1,316	..	....	.....	....	.....	.....	.....
	6 months	2	10.57	1.678	3,356	23.14	3.574	7,148	52	.992	1,984	....	.....	.....	.26
	9 months	3	39.50	8.597	17,194	17.56	3.295	6,590	2.13	1.343	2,686	....	.....	.....	2.58
	12 months	4	45.90	9.028	18,056	14.82	3.131	6,262	5.78	4.081	8,162	....	.....	.....	4.37
	15 months	5	70.66	17.57	35,140	18.54	3.698	7,396	7.50	4.717	9,434	....	.....	.....	7.52
/28	6 months	1	5.48	8.267	1,653	14.72	2.616	5,232	....	.....	.....	....	.....	.....	.17
	9 months	2	31.43	6.127	12,254	17.52	3.558	7,116	2.48	1.674	3,348	....	.....	.....	2.35
	12 months	3	53.77	12.56	25,120	16.87	3.413	6,826	5.36	4.043	8,086	....	.....	.....	5.32
	15 months	4	59.54	13.59	27,180	16.51	3.424	6,848	6.41	4.950	9,900	....	.....	.....	6.33
	18 months	5	91.55	21.60	43,200	19.15	3.868	7,736	6.69	5.408	10,816	....	.....	.....	9.15
/28	9 months	1	26.36	5.219	10,438	16.08	2.980	5,960	2.72	1.693	3,386	....	.....	.....	1.91
	12 months	2	53.10	11.72	23,440	16.66	3.431	6,862	4.68	3 457	6,914	....	.....	.....	5.65
	15 months	3	65.12	16.68	33,360	16.18	3.191	6,382	5.52	4.227	8,454	.54	.....	.....	7.40
	18 months	4	72.22	16.48	32,960	16.80	3.009	6,018	7.04	5.468	10,936	....	.....	.....	8.40
	21 months	5	107.64	25.76	51,520	19.40	3.981	7,962	8.16	5.847	11,694	....	.....	.....	12.81
/29	12 months	1	53.42	12.98	25,960	17.01	3.106	6,212	9.97	5.277	10,554	....	.....	.....	6.52
	15 months	2	66.29	17.16	34,320	14.03	2.523	5,046	3.21	6.916	13,832	.13	.....	.....	8.30
	18 months	3	90.23	22.84	45,680	12.97	2.582	5,164	5.79	9.023	18,046	1.24	.....	.....	10.72
	21 months	4	99.50	26.71	53,420	14.66	3.046	6,092	9.44	0.27	20,540	2.48	.....	.....	12.64
	24 months	5	125.62	32.74	65,480	13.31	2.712	5,424	9.52	9.627	19,254	4.18	.949	1,898	17.97
/29	15 months	1	59.30	15.44	30,880	14.00	2.723	5,446	6.10	5.184	10,368	.20	.....	.....	5.67
	18 months	2	68.60	17.44	34,880	11.70	2.511	5,022	6.20	4.965	9,930	.62	.....	.....	9.53
	21 months	3	80.0	20.62	41,240	11.70	2.466	4,932	7.70	6.321	12,642	1.30	.642	1,284	12.03
	24 months	4	90.03	24.01	48,020	11.40	2.623	5,246	8.10	6.333	12,666	3.00	1.491	2,982	13.09
	27 months	5	108.9	28.79	57,580	11.40	2.640	5,280	1.50	9.620	19,240	6.50	3.260	6,540	13.96
/29	18 months	1	66.4	17.73	35,460	14.74	2.994	5,988	9.66	7.851	15,702	.86	.....	.....	8.0
	21 months	2	70.0	18.75	37,500	11.56	2.388	4,776	1.50	9.125	18,250	.82	.....	.....	8.97
	24 months	3	82.0	22.86	45,720	13.10	2.812	5,624	1.06	8.578	17,156	2.18	1.244	2,488	11.39
	27 months	4	96.4	25.71	51,420	12.18	3.059	6,118	0.96	9.236	18,472	3.60	2.608	5,416	13.39
	30 months	5	100.0	26.67	53,340	14.00	3.294	6,588	2.26	9.671	19,342	8.74	5.070	10,140	13.51

TABLE IIa

Chemical Composition of Cane, Dry Basis

Date of Harvest	Age	Crop	Per cent Ash	Per cent SiO_2	Per cent CaO	Per cent K_2O	Per cent MgO	Per cent P_2O_5	Per cent N
2/15/28	Seed Cane	1	1.89	0.44	0.065	0.69	0.19	0.086	0.29
	3 months	2	....	....	.....	....	....	....	....
	6 months	3	2.61	0.60	0.069	0.97	0.19	0.12	0.36
	9 months	4	1.50	0.46	0.079	0.39	0.18	0.075	0.29
	12 months	5	2.03	0.37	0.056	0.88	0.16	0.097	0.25
5/26/28	3 months	1	....	....	.....	....	....	.....	....
	6 months	2	2.16	0.53	0.12	0.76	0.23	0.12	0.38
	9 months	3	1.88	0.41	0.054	0.67	0.16	0.13	0.28
	12 months	4	2.28	0.42	0.058	0.88	0.17	0.13	0.25
	15 months	5	1.93	0.39	0.059	0.79	0.17	0.14	0.22
7/23/28	6 months	1	3.11	0.57	0.15	1.00	0.35	0.16	0.44
	9 months	2	1.43	0.37	0.082	0.39	0.18	0.10	0.23
	12 months	3	1.41	0.43	0.069	0.39	0.16	0.086	0.23
	15 months	4	1.13	0.36	0.036	0.31	0.14	0.068	0.23
	18 months	5	1.54	0.33	0.044	0.59	0.12	0.086	0.21
9/21/28	9 months	1	1.47	0.29	0.090	0.48	0.21	0.093	0.21
	12 months	2	1.54	0.35	0.10	0.40	0.22	0.083	0.17
	15 months	3	1.41	0.41	0.064	0.38	0.15	0.099	0.15
	18 months	4	1.69	0.45	0.071	0.53	0.19	0.13	0.16
	21 months	5	1.88	0.37	0.051	0.72	0.14	0.13	0.14
2/15/29	12 months	1	1.27	0.34	0.069	0.32	0.18	0.090	0.19
	15 months	2	1.49	0.30	0.059	0.51	0.14	0.087	0.15
	18 months	3	1.75	0.42	0.062	0.52	0.17	0.11	0.16
	21 months	4	1.51	0.48	0.057	0.35	0.17	0.12	0.13
	24 months	5	1.78	0.48	0.054	0.56	0.15	0.15	0.12
5/22/29	15 months	1	1.11	0.40	0.075	0.19	0.18	0.09	0.16
	18 months	2	1.59	0.40	0.072	0.51	0.17	0.10	0.12
	21 months	3	1.52	0.53	0.068	0.32	0.18	0.13	0.10
	24 months	4	1.34	0.47	0.060	0.29	0.16	0.13	0.11
	27 months	5	1.77	0.56	0.058	0.49	0.14	0.16	0.12
7/23/29	18 months	1	1.21	0.33	0.062	0.38	0.15	0.11	0.10
	21 months	2	1.52	0.36	0.063	0.47	0.17	0.11	0.10
	24 months	3	1.46	0.48	0.053	0.37	0.16	0.16	0.08
	27 months	4	1.61	0.48	0.062	0.43	0.17	0.17	0.10
	30 months	5	1.81	0.49	0.050	0.56	0.17	0.25	0.09

TABLE IIb

Chemical Composition of Leaves and Tops, Dry Basis

Date of Harvest	Age	Crop	Per cent Ash	Per cent SiO_2	Per cent CaO	Per cent K_2O	Per cent MgO	Per cent P_2O_5	Per cent N
2/15/28	Seed Cane	1	....	....		..	..	...	.
	3 months	2	11.13	4.21	0.45	2.96	0.52	0.42	1.54
	6 months	3	9.20	3.20	0.33	2.87	0.40	0.38	1.13
	9 months	4	8.43	2.70	0.34	2.70	0.43	0.38	0.91
	12 months	5	9.50	3.57	0.27	3.03	0.36	0.37	1.01
5/26/28	3 months	1	10.03	3.68	0.34	2.77	0.49	0.42	1.54
	6 months	2	7.12	2.00	0.32	2.26	0.41	0.39	1.11
	9 months	3	8.36	2.77	0.39	2.50	0.45	0.32	0.96
	12 months	4	8.11	2.80	0.47	2.22	0.51	0.30	0.93
	15 months	5	7.95	2.54	0.31	2.83	0.36	0.35	0.93
7/23/28	6 months	1	7.46	2.18	0.33	2.30	0.44	0.37	0.98
	9 months	2	7.72	2.59	0.41	2.19	0.41	0.34	0.92
	12 months	3	7.79	2.37	0.34	2.63	0.35	0.34	0.81
	15 months	4	8.34	3.13	0.37	2.34	0.41	0.36	0.92
	18 months	5	8.42	3.19	0.38	2.41	0.42	0.33	0.85
9/21/28	9 months	1	6.75	1.61	0.32	2.45	0.37	0.41	1.04
	12 months	2	7.47	2.07	0.35	2.72	0.33	0.39	0.93
	15 months	3	8.05	2.69	0.29	2.72	0.31	0.39	0.86
	18 months	4	8.05	2.73	0.27	2.80	0.30	0.43	0.96
	21 months	5	7.82	2.05	0.24	2.63	0.26	0.41	0.85
2/15/29	12 months	1	7.94	2.35	0.36	2.71	0.40	0.40	1.04
	15 months	2	8.14	2.20	0.22	3.13	0.31	0.42	0.87
	18 months	3	8.33	2.06	0.25	2.99	0.30	0.43	0.92
	21 months	4	8.61	3.51	0.25	2.64	0.28	0.42	0.89
	24 months	5	9.15	3.13	0.24	3.12	0.27	0.43	0.81
5/22/29	15 months	1	7.42	2.21	0.28	2.75	0.33	0.37	0.82
	18 months	2	8.03	2.82	0.28	2.73	0.28	0.35	0.73
	21 months	3	8.45	3.13	0.28	2.69	0.31	0.37	0.72
	24 months	4	8.76	3.69	0.27	2.57	0.28	0.37	0.75
	27 months	5	8.59	3.46	0.25	2.71	0.26	0.36	0.79
7/23/29	18 months	1	8.89	3.43	0.30	2.74	0.31	0.45	0.77
	21 months	2	8.44	3.10	0.24	2.78	0.27	0.47	0.71
	24 months	3	9.00	3.59	0.26	2.73	0.28	0.47	0.63
	27 months	4	8.07	3.62	0.27	2.26	0.29	0.44	0.69
	30 months	5	9.14	4.15	0.25	2.53	0.28	0.48	0.75

TABLE IIc

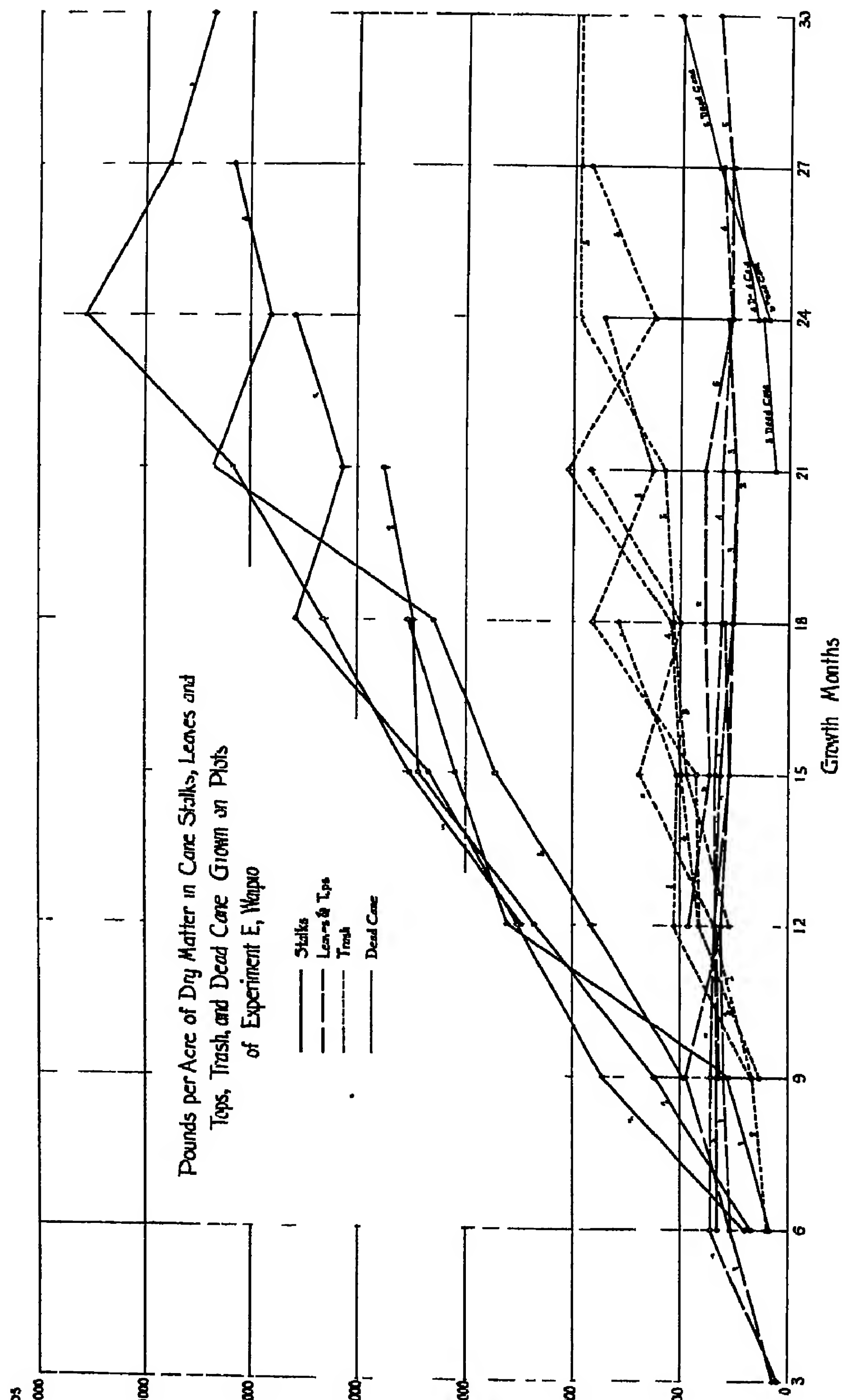
Chemical Composition of Trash, Dry Basis

Date of Harvest	Age	Crop	Per cent Ash	Per cent SiO_2	Per cent CaO	Per cent K_2O	Per cent MgO	Per cent P_2O_5	Per cent N
2/15/28	Seed Cane	1	..	....	....	....	...	...	....
	3 months	2	...	....	...	....	....	....	...
	6 months	3	...	...	....	....	....	..	...
	9 months	4	9.17	5.57	0.57	0.81	0.47	0.078	0.39
	12 months	5	9.72	5.73	0.45	0.86	0.36	0.12	0.51
5/26/28	3 months	1	....	...	...	....	...	....	....
	6 months	2	14.16	9.16	0.85	0.90	0.72	0.080	0.37
	9 months	3	11.99	7.52	0.58	1.26	0.49	0.072	0.32
	12 months	4	10.00	6.01	0.63	0.94	0.62	0.084	0.37
	15 months	5	11.56	7.31	0.58	1.35	0.58	0.089	0.40
7/23/28	6 months	1	....	..	....	....	....	...	....
	9 months	2	10.16	6.12	0.78	0.80	0.62	0.11	0.43
	12 months	3	9.22	4.98	0.57	1.28	0.45	0.11	0.37
	15 months	4	8.89	4.92	0.52	1.31	0.48	0.12	0.40
	18 months	5	9.33	5.65	0.51	1.15	0.46	0.11	0.37
9/21/28	9 months	1	10.65	6.47	0.78	0.79	0.72	0.078	0.33
	12 months	2	8.20	4.12	0.70	1.01	0.58	0.096	0.34
	15 months	3	8.80	5.27	0.58	0.87	0.42	0.079	0.29
	18 months	4	9.27	5.28	0.55	1.09	0.49	0.15	0.37
	21 months	5	9.97	5.64	0.45	1.56	0.46	0.12	0.38
2/15/29	12 months	1	9.73	6.16	0.65	0.42	0.42	0.078	0.32
	15 months	2	9.55	6.56	0.58	0.60	0.36	0.10	0.33
	18 months	3	9.43	6.61	0.49	0.74	0.34	0.12	0.34
	21 months	4	10.39	7.82	0.44	0.51	0.31	0.086	0.30
	24 months	5	10.31	7.76	0.39	0.47	0.29	0.092	0.34
5/22/29	15 months	1	8.37	4.87	0.56	1.04	0.48	0.11	0.32
	18 months	2	9.27	5.33	0.40	1.61	0.37	0.087	0.26
	21 months	3	10.34	6.68	0.49	1.32	0.41	0.096	0.30
	24 months	4	10.42	7.13	0.46	1.10	0.42	0.11	0.26
	27 months	5	10.54	7.58	0.41	0.95	0.33	0.092	0.28
7/23/29	18 months	1	12.11	7.40	0.68	1.55	0.49	0.11	0.30
	21 months	2	11.11	7.43	0.48	1.29	0.32	0.14	0.26
	24 months	3	11.99	7.98	0.43	1.55	0.38	0.16	0.28
	27 months	4	11.98	7.99	0.38	1.64	0.34	0.15	0.27
	30 months	5	12.39	8.45	0.40	1.57	0.37	0.19	0.32

TABLE IId

Chemical Composition of Dead Cane, Dry Basis

Date of Harvest	Age	Crop	Per cent Ash	Per cent SiO_2	Per cent CaO	Per cent K_2O	Per cent MgO	Per cent P_2O_5	Per cent N
2/15/29	24 months	5	3.08	1.10	0.15	0.56	0.33	0.13	0.23
5/22/29	21 months	3	2.48	0.73	0.12	0.66	0.28	0.15	0.20
	24 months	4	2.33	0.87	0.13	0.50	0.29	0.15	0.26
	27 months	5	2.38	0.68	0.95	0.71	0.23	0.17	0.17
7/23/29	24 months	3	2.40	0.66	0.11	0.70	0.28	0.16	0.17
	27 months	4	1.77	0.52	0.073	0.52	0.19	0.17	0.15
	30 months	5	2.23	0.81	0.10	0.56	0.24	0.18	0.14



Pounds per Acre of Dry Matter in Cane Stalks, Leaves and Tops, Trash, and Dead Cane Grown on Plots of Experiment E, Waipio
Stalks
Leaves & Tops
Trash
Dead Cane
Lbs
70000
60000
50000
40000
30000
20000
10000
0
3
6
9
12
15
18
21
24
27
30
Growth Months

Fig. 1

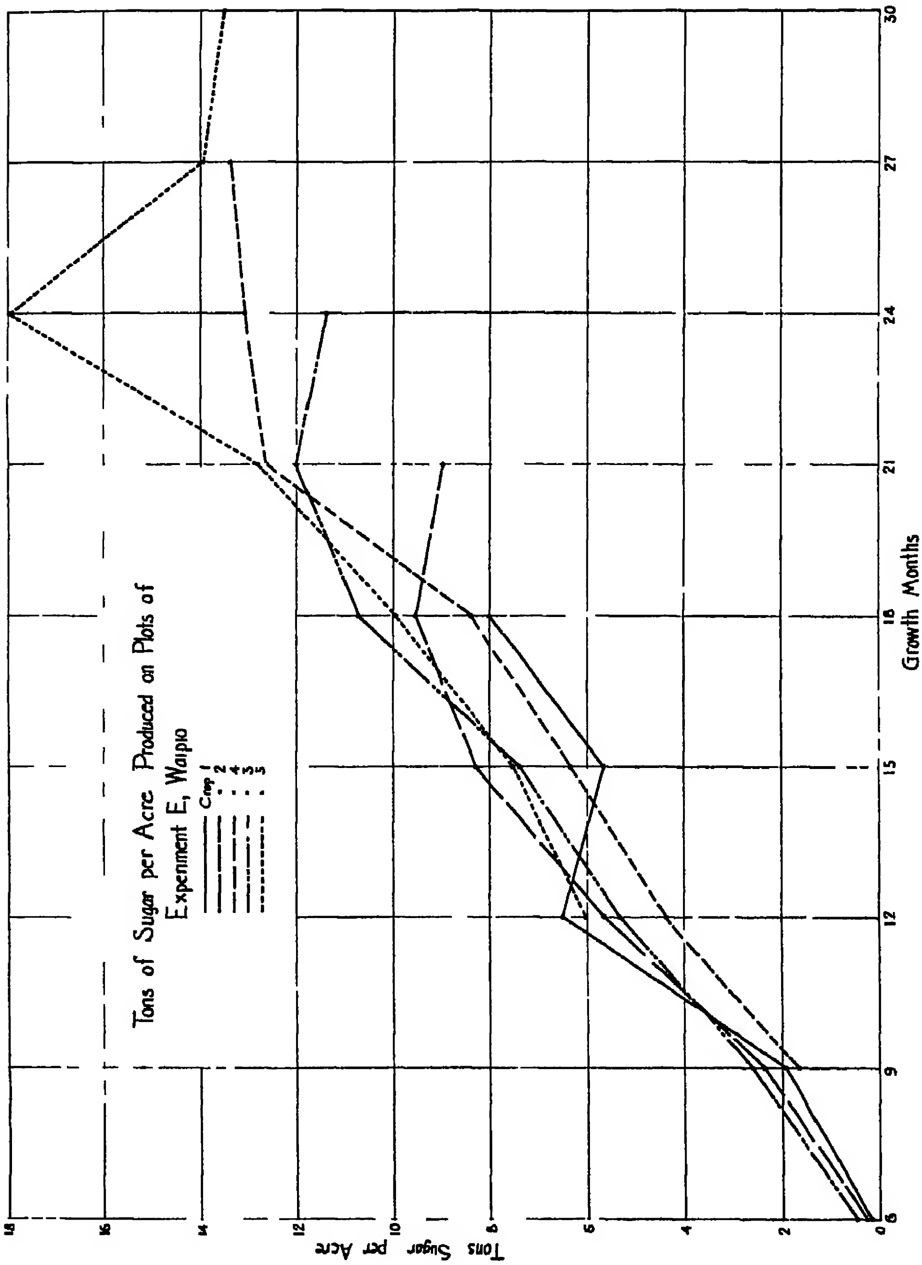
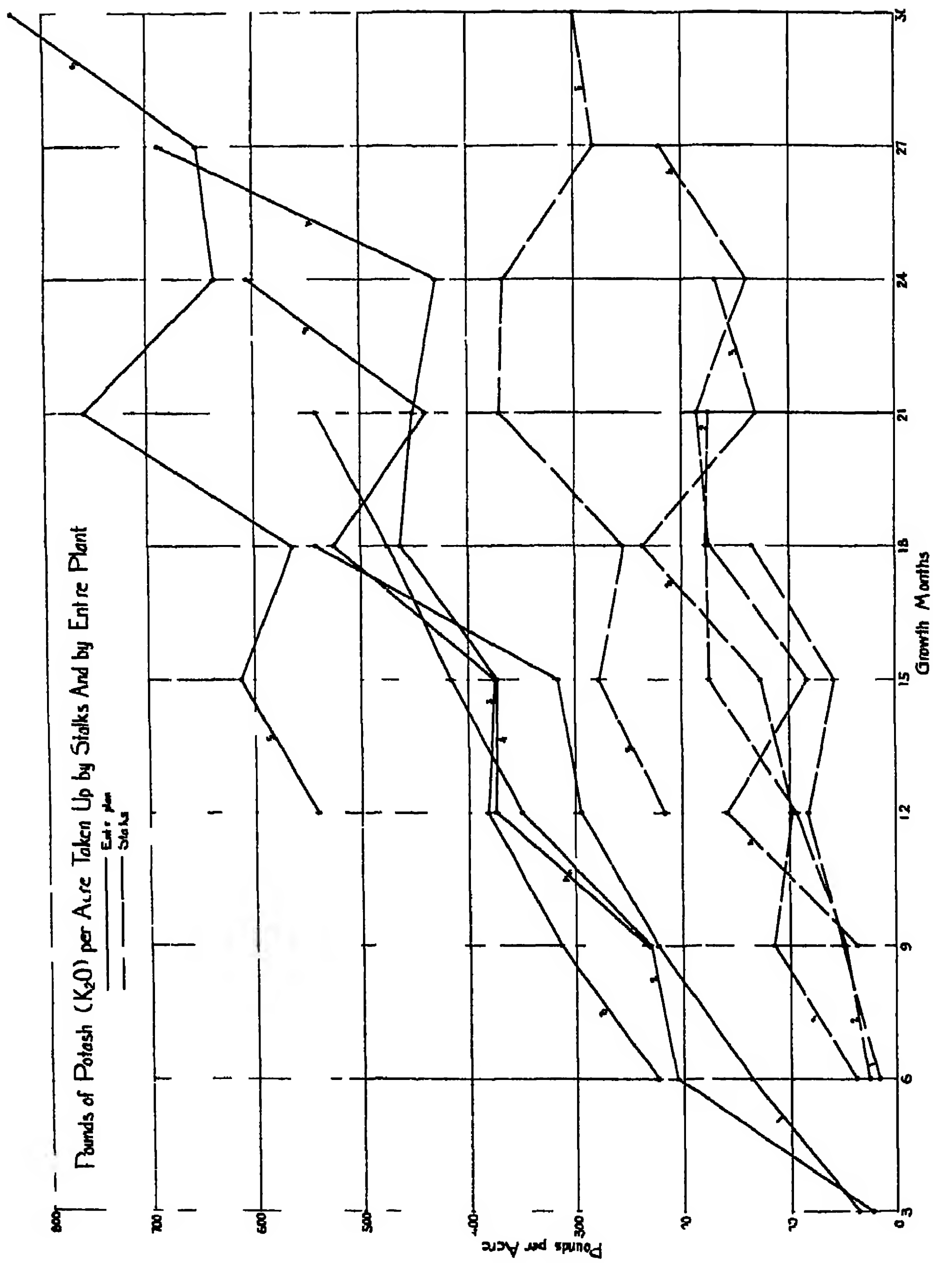
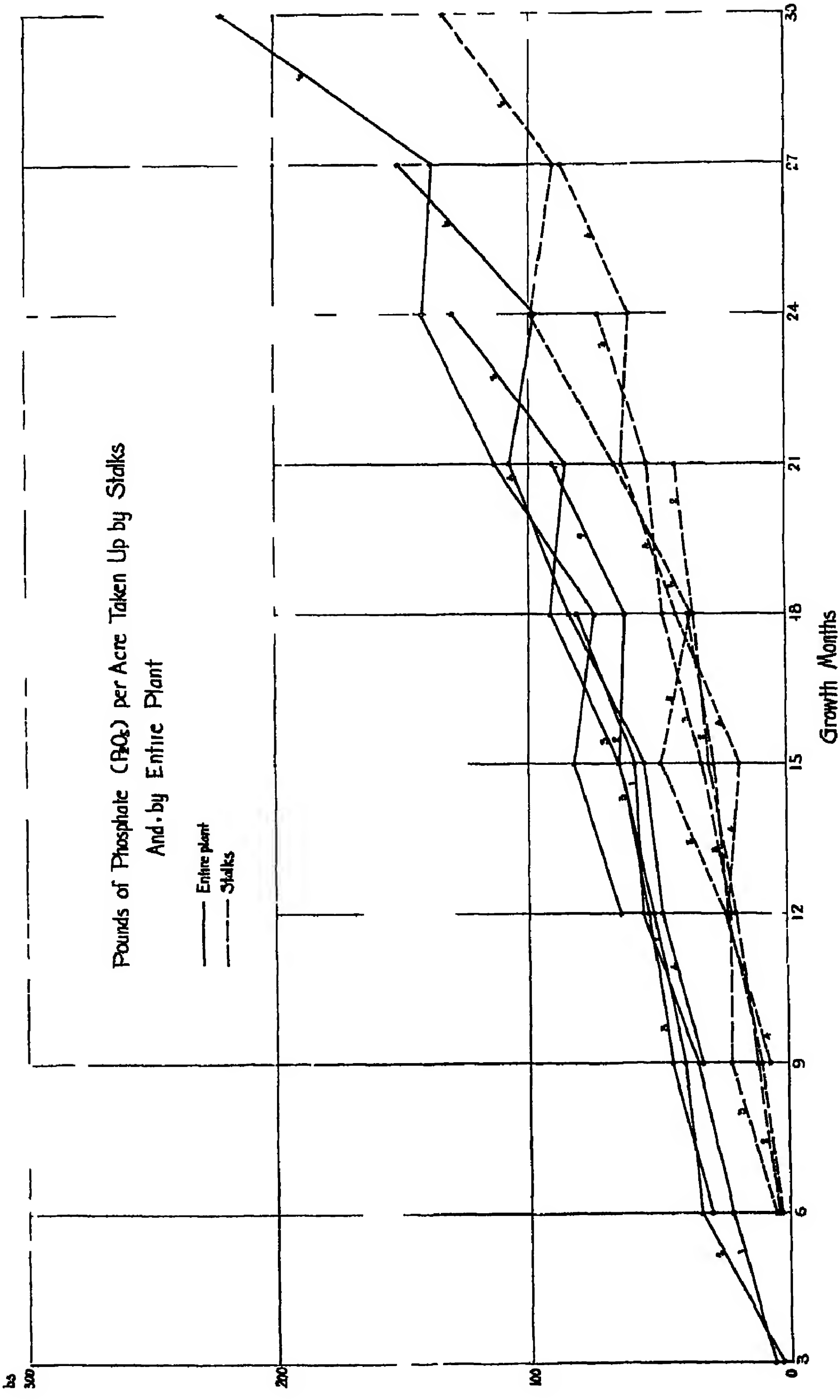

Tons of Sugar per Acre Produced on Plots of
Experiment E, Waipio
Crop 1
" 2
" 4
" 3
" 5
Tons Sugar per Acre
0
2
4
6
8
10
12
14
16
18
6
9
12
15
18
21
24
27
30
Growth Months

Fig. 2



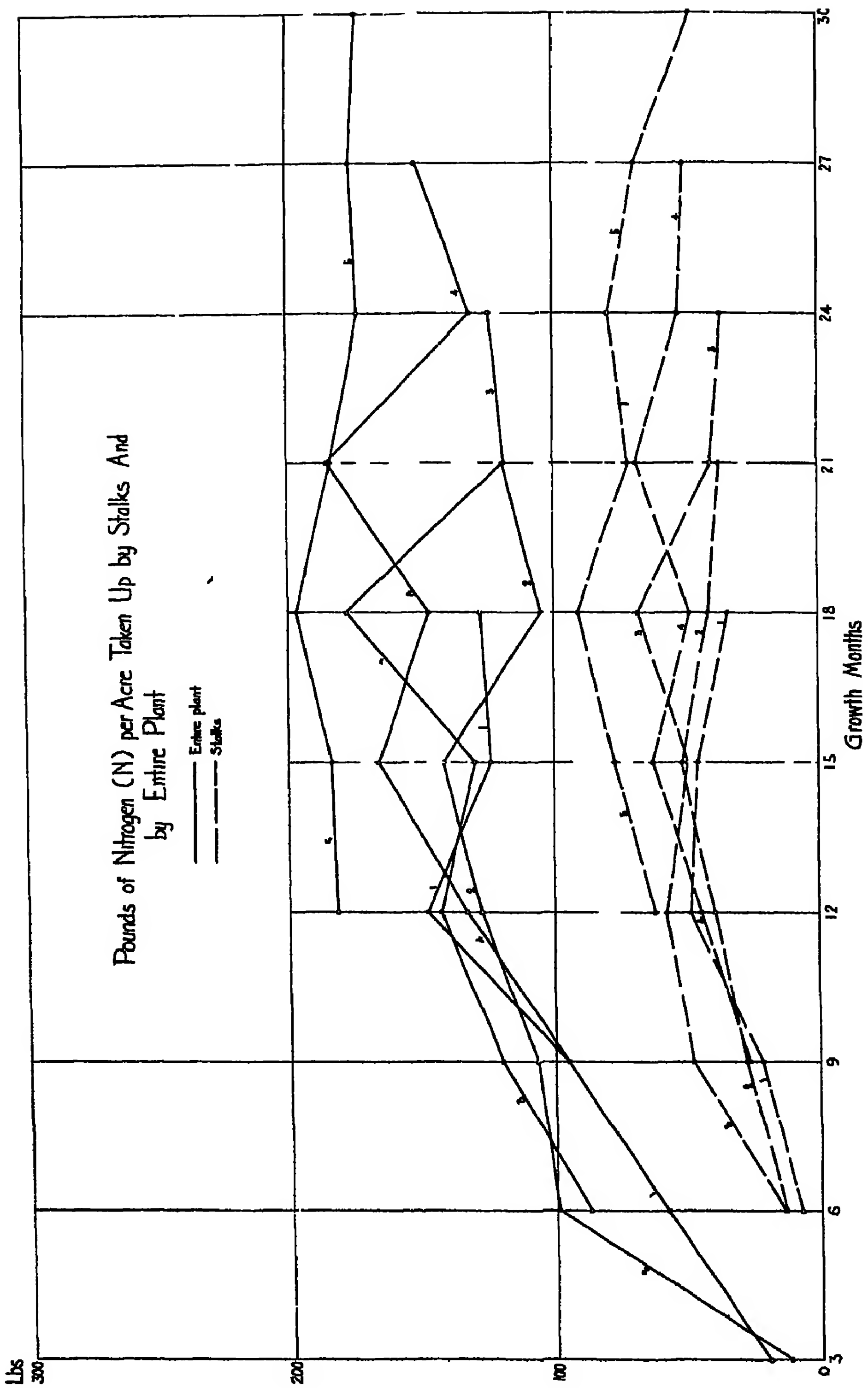
Pounds of Potash (K_2O) per Acre Taken Up by Stalks And by Entire Plant
Entire plant
Stalks
Pounds per Acre
800
700
600
500
400
300
0
3
6
9
12
15
18
21
24
27
30
Growth Months

Fig 3



Pounds of Phosphate (P2O5) per Acre Taken Up by Stalks
And by Entire Plant
Entire plant
Stalks
Growth Months
lbs
300
200
100
0
3
6
9
12
15
18
21
24
27
30

Fig 4


Pounds of Nitrogen (N) per Acre Taken Up by Stalks And
by Entire Plant
Entire plant
Stalks
Lbs
300
200
100
0
3
6
9
12
15
18
21
24
27
30
Growth Months

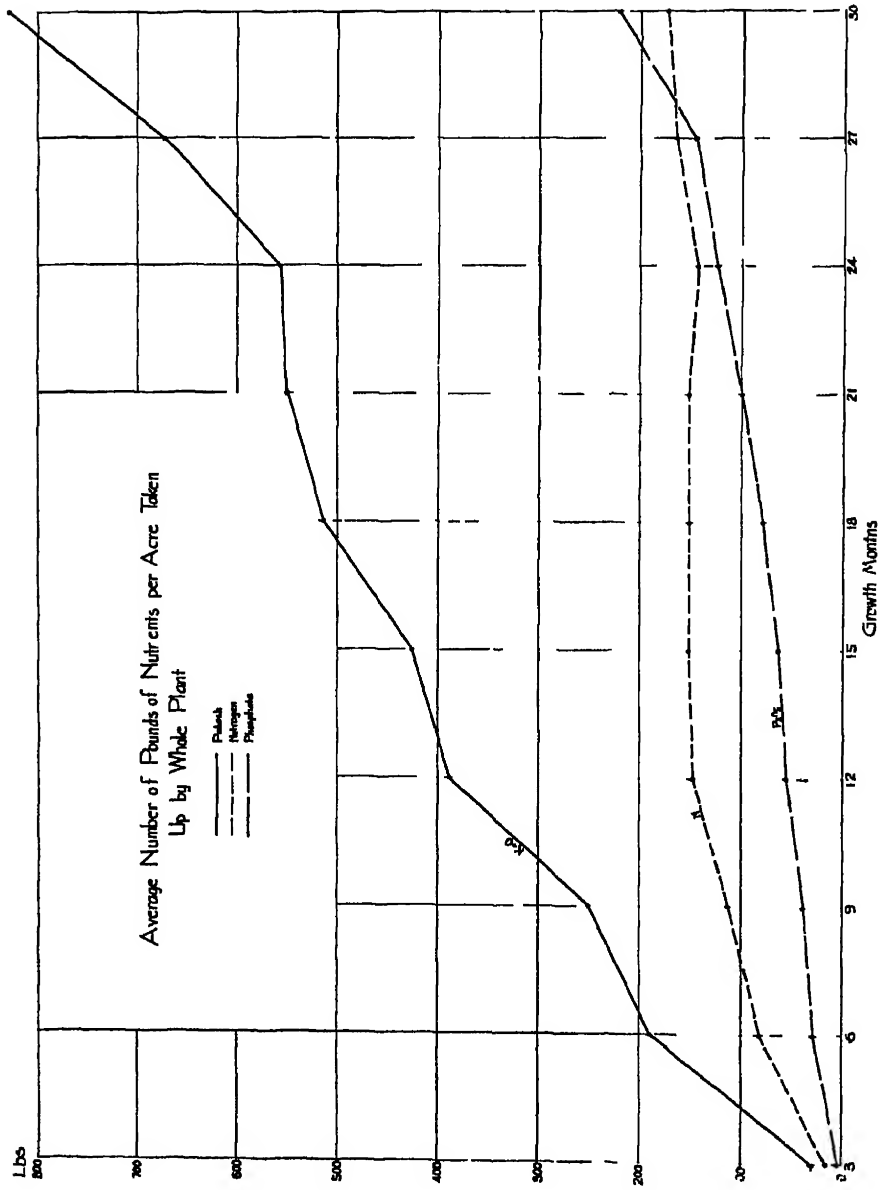
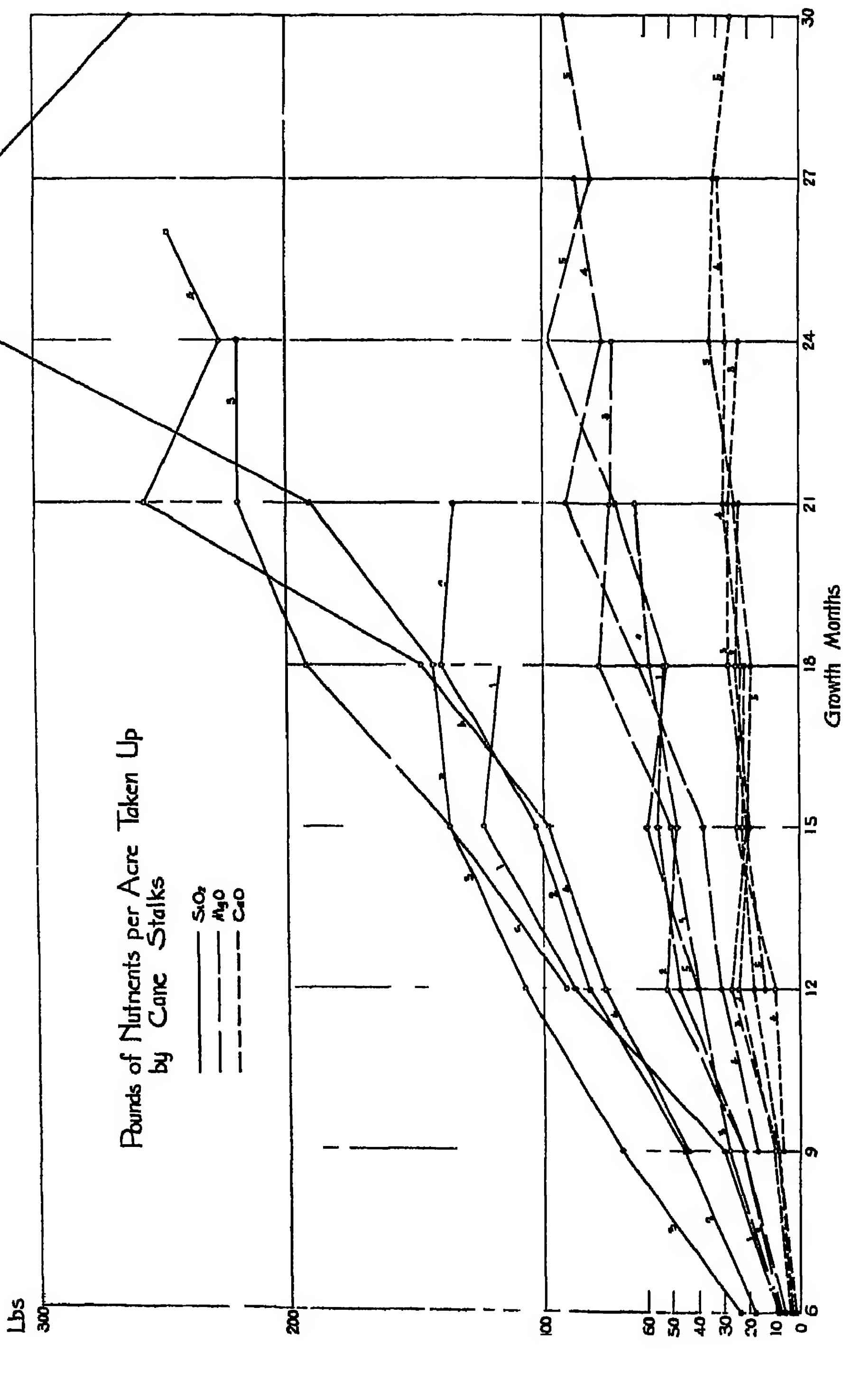

Average Number of Pounds of Nutrients per Acre Taken
Up by Whole Plant
Lbs
800
700
600
500
400
300
200
3
6
9
12
15
18
21
24
27
30
Growth Months

Fig. 6


Pounds of Nutrients per Acre Taken Up
by Cane Stalks
SiO2
MgO
CaO
Lbs
300
200
100
60
50
40
30
20
10
0
6
9
12
15
18
21
24
27
30
Growth Months

Fig

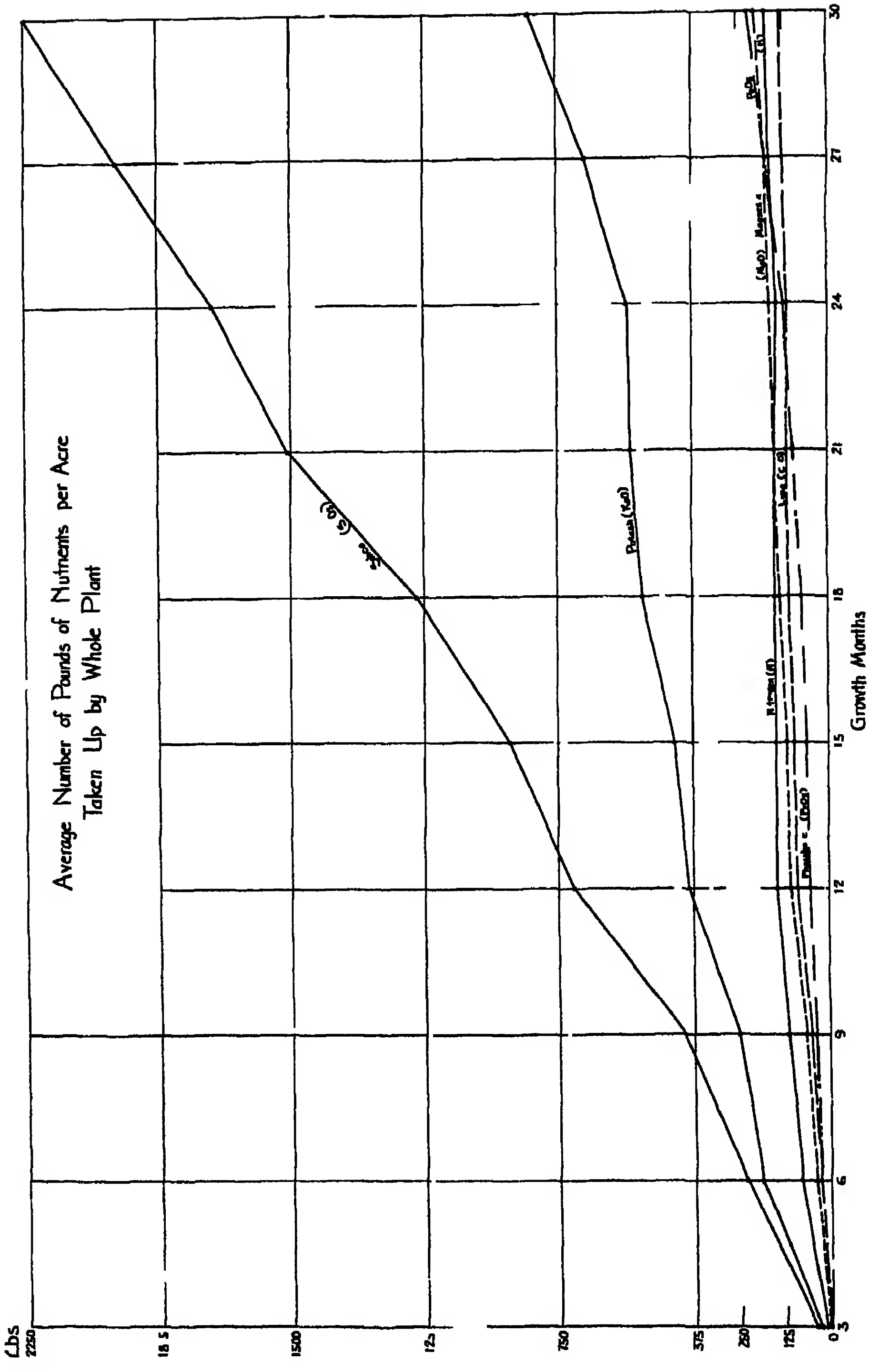
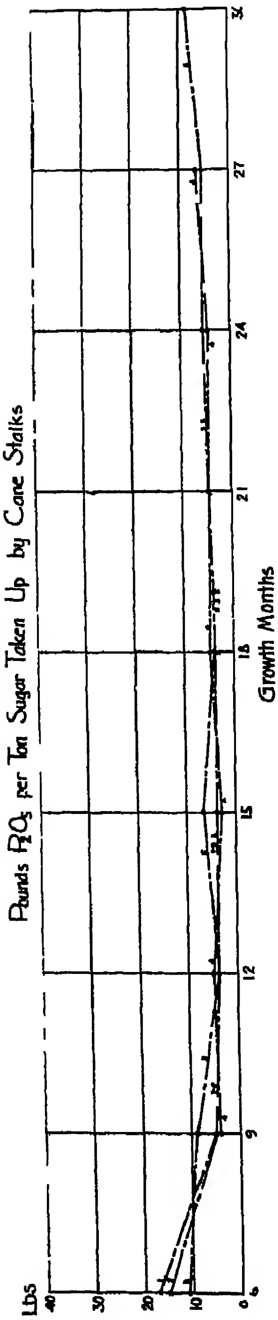
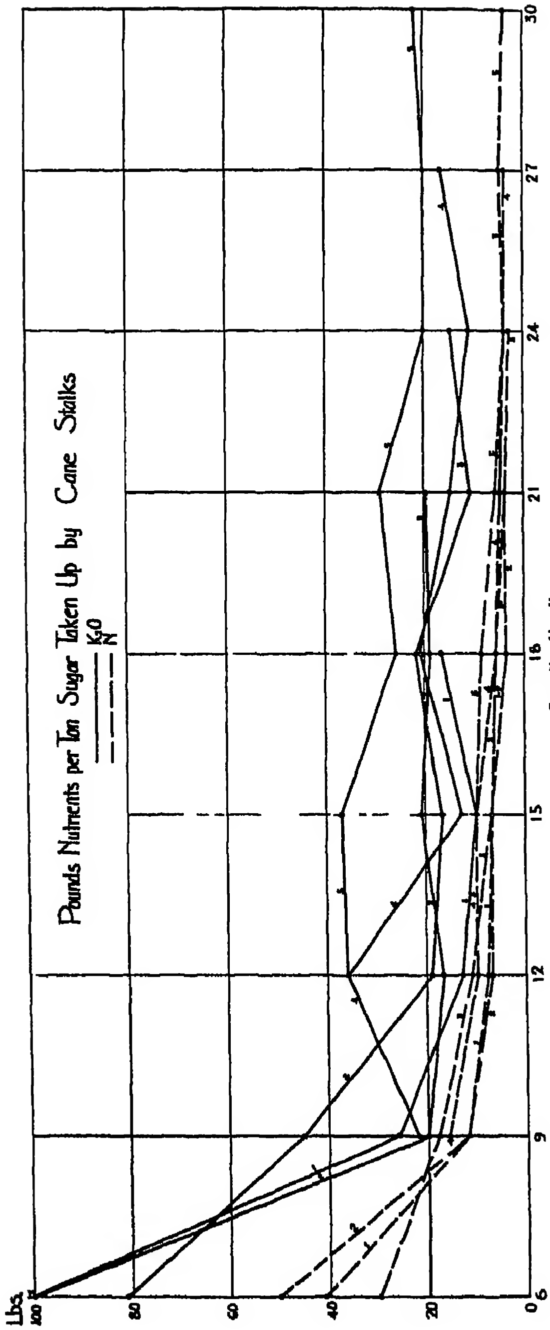

Average Number of Pounds of Nutrients per Acre
Taken Up by Whole Plant
Lbs
2250
18 5
1500
12s
750
375
250
125
0
3
6
9
12
15
18
21
24
27
30
Potash (K2O)
Growth Months

Fig. 8


Pounds P_2O_5 per Ton Sugar Taken Up by Cane Stalks
Lbs
40
30
20
10
0
6
9
12
15
18
21
24
27
30
Growth Months


Pounds Nutrients per Ton Sugar Taken Up by Cane Stalks
K_2O
N
Lbs
100
80
60
40
20
0
6
9
12
15
18
21
24
27
30
Growth Months

Figs. 9 and 10

The Determination of Soil Reaction by Hydrogen Electrode

By Ritchie R. Ward

In a paper which appeared in *The Hawaiian Planters' Record* some six years ago, King (1) gave a clear development of the relation between hydrogen ion concentration and the pH of a solution. These terms are coming into steadily increasing use in the literature, and a thorough understanding of their significance is prerequisite to an appreciative reading of this material.

Since the appearance of this paper, the use of the hydrogen electrode for measuring hydrogen ion concentration has become more general. In the present paper, an attempt will be made to show how acidity, and particularly soil reaction, is determined with this apparatus.

In outline, the method consists of setting up a galvanic cell, one of whose electrodes is hydrogen-hydrogen ion, and the other mercury, calomel and chloride ion. When such a cell is constructed, the two electrodes being connected across a liquid junction, an electromotive force will be set up, the value of which depends, among other things, on the concentration of hydrogen ion in contact with the hydrogen electrode. By keeping other variables constant, it is possible to measure the hydrogen ion concentration by measuring the value of the electromotive force of the cell.

It should be emphasized that this electromotive force is the reversible one, set up when the electromotive force of the cell is exactly balanced by a counter electromotive force of external origin, such as from a storage battery. In this way only, may the maximum work of the cell reaction be measured. The value of this maximum work is an entirely different quantity from that produced when the cell reaction is allowed to proceed irreversibly. This will be seen to be analogous to the case of a simple heat engine. Here, too, the maximum work is not measured unless the engine is exactly balanced by an external force. In either case, the measurement must be taken at equilibrium.

In general, any chemical reaction is accompanied by a change of energy. A common example of this effect is the burning of carbon to carbon dioxide with the liberation of heat. Now, by taking into account the amount of heat liberated, and the work done upon the surroundings by such a reaction, it is possible to derive a measure of the tendency of that reaction to take place. Another, and better, measure of this tendency also takes into account the change in so-called entropy* during the reaction. This latter quantity is known as the free energy, or chemical potential, and is analogous to fluid head or electrical voltage. In fact, the free energy may be used to calculate the electrode potential of a reaction in volts, and this is often done.

Returning to the consideration of the cell, which may be represented thus:

$$Hg, HgCl(s), Cl^{-}(N/10) \parallel KCl(sat.) \parallel H^{+}, H_2(g), Pt,$$

* The concept of entropy involves many ramifications, but for the purpose of the present discussion, it may be considered as that portion of the energy of a substance which is unavailable for the performance of useful work.

it will be seen that the following reactions occur:

(a) $Hg + Cl = HgCl + E$,
(b) $H^+ + E^- = \frac{1}{2} H_2(g)$.

Each of these reactions has a definite potential in the sense discussed above, which is expressible in volts. This value will, of course, vary as the concentration of the ions H^+ and Cl^- vary.

For any reaction, such as

$$lL + mM + \ldots = rR + sS + \ldots + NE$$

the value of the electromotive force of the reaction may be calculated from the equation:

$$E = E^\circ - \frac{RT}{NF} \ln \frac{a_R^r \cdot a_S^s}{a_L^l \cdot a_M^m} \qquad (I)$$

where E° is the electrode potential when all the substances are at unit activity, R is the gas constant expressed in calories per degree, T is the absolute temperature, N is the number of equivalents, and F is the value of the Faraday, expressed in calories per volt equivalent. The natural logarithm is represented by ln, and a† is the activity.

Applying this equation to reaction (*a*), we get

$$E = E^\circ - \frac{RT}{F} \ln \frac{1}{a_{Cl}} \qquad (II)$$

From the work of Lewis and Randall (*2*), $E^\circ = -.2700$ volts. The same workers have determined the activity of chloride ion from freezing point data, and have found it to be 0.0794 in tenth normal solution. Either the tenth normal or the normal calomel electrode may be employed, but inasmuch as the tenth normal one is in more general use, it will be the only one discussed here. Substituting these values in the equation:

$$E = -0.2700 - \frac{RT}{F} \ln \frac{1}{0.0794}$$

$$E = -0.3351$$

This, then, is the potential of the tenth normal calomel electrode at 25° C.

For reaction (*b*)

$$E = E^\circ - \frac{RT}{F} \ln \frac{(H_2)^{\frac{1}{2}}}{(H^+)} \qquad (III)$$

* The symbol E^- represents an electron. A reaction in which an electron is gained is a reduction, and, conversely, an oxidation.

† The activity may be regarded as a corrected concentration; in fact, it is equal to the concentration in an infinitely dilute solution. Its value is determined by measurements of the freezing point lowering or boiling point raising of solutions.

Here, E° has, by international agreement, been arbitrarily defined as zero, the activity of the hydrogen gas is taken as the pressure, and in very dilute solutions, the activity of the hydrogen ion is equal to its concentration. When substituting numerical values in the equation:

$$E = 0 - 0.05915 \log \frac{1}{(H^+)}$$

Adding (1) and (2), there appears for the reaction

$$Hg(l) + H^+ + Cl^- = HgCl(s) + \tfrac{1}{2} H_2(g),$$

$$E = -0.3351 - 0.05915 \log \frac{1}{(H^+)}$$

But by definition, $pH = \log \frac{1}{(H^+)}$, whence

$$pH = -\left(\frac{E + 0.3351}{0.05915}\right)$$

It may be noted that the value of E for the above reaction will be negative, since the reaction proceeds spontaneously to the left. As will be seen from the equation, the only measurement necessary to a determination of the pH of a solution is the voltage E, but the dependence of the entire procedure upon the results of previous workers in pure science is quite obvious.

The value of the electromotive force of this cell may, however, be affected in a number of ways other than those discussed above.

It will be noted that there are three liquid junction potentials as the cell is ordinarily set up. These are all potassium chloride junctions, and it is rather important to see why they are so small as to be negligible for all practical purposes.

In general, liquid junction potentials are due to the difference in ionic mobilities of the anions and cations in a solution. Suppose a long tube filled with dilute hydrochloric acid is under a uniform potential gradient of one volt per centimeter. It has been found that the hydrogen ion moves with a velocity of 32.50×10^{-4} centimeters per second in such a tube, and the chloride ion moves with a velocity of 6.78×10^{-4} centimeters per second. The relative velocities of free movement of these ions will be in much the same ratio.

Now if a solution of hydrochloric acid is in contact with pure water at an imaginary interface, both hydrogen ions and chloride ions will tend to diffuse from the solution across the boundary into the water. But the hydrogen ions move about five times as fast as the chloride ions, so that there will eventually be more positively charged ions on the water side of the boundary, and more negatively charged ions on the hydrochloric acid side. An electromotive force corresponding to this distribution of charges will be set up across the junction.

The same general considerations apply to two solutions of different concentrations. This is the type of liquid junction commonly met with in cells for electrode

potential measurements. In such cases it is possible to calculate the potential across a liquid junction from ionic mobility figures and apply the correction so derived. Sometimes, also, the effect is greatly reduced by construction of flowing junctions, so that practically no diffusion can occur.

It would be simpler and more satisfactory if a solute could be found whose anions and cations moved at the same rate. In such a case no accumulation of charges would occur on either side of a boundary, and consequently no electromotive force would be set up. This is very nearly true for potassium chloride, the absolute velocity of potassium ion being 6.70×10^{-4} centimeters per second, and that of chloride ion being 6.78×10^{-4}. Accordingly, potassium chloride is generally used for liquid junctions of this kind.

It will be recalled that in applying Equation III, it was assumed that the hydrogen was at atmospheric pressure. This is not quite true, since the solution exerts a partial pressure, and the hydrogen is below atmospheric by a corresponding amount.

As an example, the effect of pure water vapor on the pH may be calculated. The vapor pressure of water at 25° C., is 25 mm, whence the actual hydrogen pressure over the solution is (760-25)/760, or 0.967 atmospheres. Suppose that the voltage read on the potentiometer is —0.7491, which is the value for pH = 7.0 when no correction is made for the reduced hydrogen pressure. Using the equation without transposition:

$$-0.7491 = E = -0.3351 - 0.05915\ (.967)^{1/2}\ \text{pH}$$

so that pH = 7.10.

It will then be seen that the vapor pressure of the water affects the result by 0.10 pH units.

In determining the pH on soils, the reaction will not be affected to as great an extent as indicated above, since the presence of a solute lowers the vapor pressure of the water.

In this connection it may be pointed out that the solution must be completely reduced so that it will support one atmosphere of hydrogen, before the voltage is read.

In the case of a soil which is high in carbonates, and is otherwise poorly buffered, the following equilibrium is established:

$$2H^+ + CO_3^= = H^+ + HCO_3 = H_2CO_3 = H_2O + CO_2$$

When hydrogen is bubbled through the solution, carbon dioxide is carried off with it, and the equilibrium is shifted to the right, according to le Chatelier's rule. This will continue until the reaction comes practically to completion, and inasmuch as hydrogen ion is involved in the equilibrium, the pH will also change. The two readings obtained after fifteen minutes and after an hour's bubbling with hydrogen may differ widely.

In order to avoid this effect, the determination may be made in special apparatus in which the hydrogen is brought into equilibrium with the solution without bubbling, and the correction for the partial pressure of the carbon dioxide applied.

This is done in a manner exactly similar to the correction for the partial pressure of water vapor cited above.

It is also possible to determine the partial pressure of the carbon dioxide from the solution, and use a corresponding mixture of hydrogen and carbon dioxide for bubbling through the regular Hildebrand electrode. In this way the equilibrium is not affected by the bubbling of gas through the solution.

Finally, the effect of temperature differences on the electromotive force of the cell may be calculated. The Gibbs-Helmholtz equation gives this effect:

$$E + \frac{\Delta H}{NF} = T\frac{dE}{dT}$$

Here ΔH is the molal heat of the cell reaction, which may be obtained by measurements with a calorimeter, or more accurately, by calculation from electrode potential data. The other symbols have the same significance as noted above, while dE/dT is the differential coefficient of the voltage with respect to temperature

Lewis and Randall give $\Delta H = 8291$ calories, and using the value —0.7491 volts for E, it follows that

$$\frac{dE}{dT} = \frac{-0.7491 + \frac{8291}{23074}}{298.1}$$

at a temperature of 25° C. Whence,

$$\frac{dE}{dT} = -0.00131,$$

so that the electromotive force of the cell decreases 1.31 millivolts for each degree rise in temperature. This corresponds to a change in pH of about one-tenth of a point for a five-degree temperature increment.

Thus, it is apparent that while many factors influence the electromotive force of a galvanic cell such as is used in determining the hydrogen ion concentration of solutions, all those which are of significant influence may be held constant. There then remain but two variables, the independent variable corresponding to the pH of the solution, and the dependent variable corresponding to the voltage. When one is measured, the other may be certainly known, for any set of conditions.

The process may be thought of as being much the same as that employed in weighing with a sensitive balance. In the latter case, two gravitational forces are balanced, and the known magnitude of one gives the magnitude of the other. So, similarly, in the cell, two opposing electrical forces are delicately balanced against each other, and precisely analogous conditions obtain.

Summary

1 The reaction which occurs in a typical cell used in determining pH has been discussed.

2. Equations have been presented for calculating the electromotive force of such a cell.

3. It has been shown how the voltage of the cell is affected by changes in temperature, pressure and composition.

LITERATURE CITED

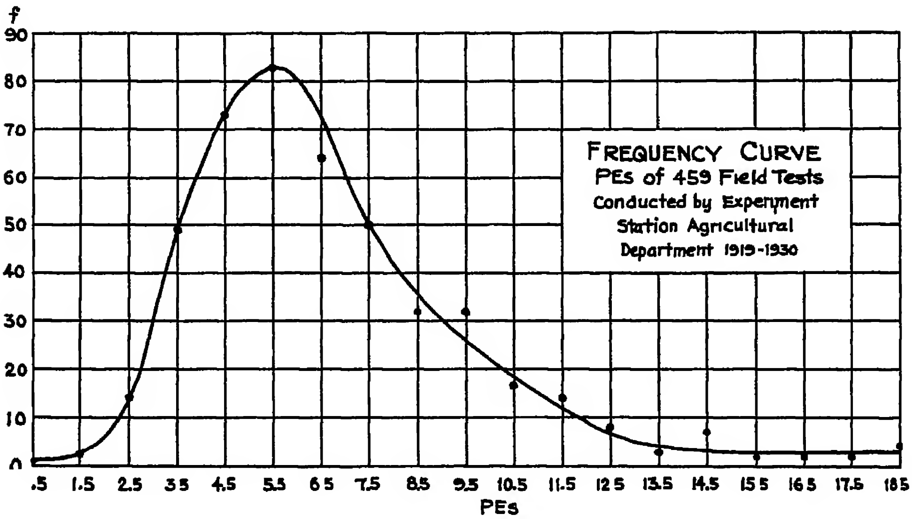
1 King, R. H. 1924. A discussion of the meaning of the terms hydrogen ion concentration and pH values of solutions. Hawaiian Planters' Record, Vol. XXVIII, pp 120-128.

2. Lewis, Gilbert N., and Randall, Merle. 1923. Thermodynamics and the free energy of chemical substances. McGraw Hill Book Co.

A Study of the Probable Error of a Single Plot from Field Tests with Sugar Cane in Hawaii

By Ralph J. Borden

During the past ten years, a considerable amount of valuable data concerned with field experiments that have been conducted by the agricultural department of the Experiment Station, H. S. P. A., have been collected. When Dr. H. H. Love, of Cornell University, visited us in the fall of 1929, he suggested that a critical statistical examination of this mass of data might be very enlightening to our agricultural workers, and that undoubtedly it would help us to see where our field experimental technique might be improved. Consequently, plans were made to study the available data and the presentation that follows summarizes the results of what was found.



Method

A total of 459 field tests furnished the basic information. In each test, the individual plot yields were recorded and then reduced to percentages of their mean or "Treatment" yield, in order that we might have yield figures for all plots in the test upon a common basis for our statistical examination. The accompanying table shows the form on which our data were recorded and the manner in which our calculations were made. It will be noted that the percentage PEs for each "Treatment" was calculated, as well as the per cent PEs for the whole experiment. This served as a check on our calculations, and also furnished the data for studies concerned with various "Treatments".

When plotted for a frequency curve (see figure) the PEs for our tests show a skewed type of curve, which is not uncommon when results of field tests are thus

plotted, and it is not surprising to find a considerably greater number of tests that deviate from a normal distribution curve in the upper range than at the lower points. (These large deviations are no doubt due to our extreme variations in soil fertility, and include some rather large errors unknowingly introduced through difficult harvesting operations. From this frequency curve, and using the formula suggested by J. W. Mellor in his "Higher Mathematics for Students of Chemistry and Physics," for the rejection of data supposedly due to suspected observations, it was calculated that any experiment that carried a PEs of 16 per cent or more might be rejected. This resulted in the rejection of eight tests, and consequently our studies were based on the 451 cases that remained.

Plantation, Hilo Sugar Co. **Experiment No.** 37FN. **Crop Year** 1930. **Field** 51, Wainaku. **Elevation,** 400 feet. **Variety,** Yellow Caledonia. **Size of Plot,** .1 acre. **Plant or Ratoon,** plant. **Date Harvested,** Feb. 1, 1930. **Age at Harvest,** 21 months. **No. of Lines,** 6. **Length of Lines,** 132 feet. **Guard rows eliminated,** 2. **Object:** Forms of Nitrogen.

Series	No. of Plots	Treatment	Total Plant Food N	P_2O_5	K_2O
A	7	N from Nitrate of Soda	226	48	240
B	7	N from Leunasaltpeter	226	48	240

Series	Plot No.	Area Acre	Yield T. C. A.	Mean Yield	Yield Per Cent of Mean	D	D^2
A	1	.066	89.4	...	100.9	+ .9	.81
	3	.066	88.6	...	100.	.....	0.
	5	.066	94.0	...	106.0	+ 6.0	36.00
	7	.066	86.2	...	97.2	— 2.8	7.84
	9	.066	85.7	...	96.7	— 3.3	10.89
	11	.066	91.5	...	103.2	+ 3.2	10.24
	13	.066	85.1	88.6	96.0	— 4.0	16.00
						+10.1 —10.1	81.78
B	2	.066	93.7	...	109.9	+ 9.9	98.01
	4	.066	85.9	...	100.8	+ .8	.64
	6	.066	84.4	...	99.0	— 1.0	1.00
	8	.066	82.2	...	96.4	— 3.6	12.96
	10	.066	89.1	...	104.5	+ 4.5	20.25
	12	.066	78.2	...	91.7	— 8.3	68.89
	14	.066	83.2	85.2	97.6	— 2.4	5.76
						+15.2 —15.3	207.51

For Treatment A:

$$S.\ D. = \sqrt{\frac{\Sigma D^2}{N-1}} = \sqrt{\frac{81.78}{6}} = 3.69\%$$

$$PEs = .6745\ S.\ D. = 2.49\%$$

For Treatment B:

$$S.\ D. = \sqrt{\frac{207.51}{6}} = 5.88\%$$

$$PEs = 3.97\%$$

For Test Area:

$$S.\ D. = \sqrt{\frac{81.78 + 207.51}{13}} = \sqrt{\frac{289.29}{13}} = 4.72$$

$$PEs = .6745\ S.\ D. = 3.18 \text{ per cent}$$

Detail

The study aimed to answer a number of questions.

(a) *What is the probable error of a single plot (PEs) for cane field experiments as conducted in Hawaii?*

The answer to this question should indicate the variation that exists in our experimental areas and the degree of refinement of our experimental technique. It should give us some idea of how we may modify the customary manner of laying out and conducting field tests, in order to eliminate or lessen those conditions which often make it difficult to interpret their results.

Due to the varied conditions under which our cane field tests are carried on, this question was subdivided in order to note the effect of the two greatest differences, irrigated vs. non-irrigated cane, upon the PEs in tests conducted thereunder.

The probable error for a single plot, when all 12,271 plots contained in our 451 tests are considered, was found to be 6.6 per cent; of the 3,569 plots contained in 133 tests on unirrigated cane, the PEs is 6.8 per cent; of the 8,702 plots in the 318 tests conducted on irrigated lands, the PEs is 6.5 per cent. From this it would appear that the variation which exists in our field experiments, whether conducted on irrigated or upon unirrigated areas, is very nearly equal. An analysis of the conditions which are the greatest factors affecting our experimental error, tends to show that while differences in soil moisture content on irrigated lands may cause a large error which is not a factor on unirrigated cane, greater soil variation exists on the shallow upland areas of the non-irrigated plantations than on the deeper more fertile soils of the other group. Presumably, therefore, the adverse effect of one major factor upon the variability within our experiment is offset by the advantage of the other factor.

(b) *Does the variation within our test area, as indicated by the PEs, change with the age of the field?*

This question aimed to secure confirmation or refutation for various expressions of opinion regarding the effect of stand as a factor of variability in field tests with cane.

The problem was attacked from two angles:

1. The PEs for both irrigated and non-irrigated cane of all plant, first ratoon, second ratoon, and third ratoon (plus a few 4th, 5th and 6th) crops was calculated. The results are summarized as follows:

	Non-Irrigated Cane		Irrigated Cane	
Age of Field	No. of Tests	PEs	No. of Tests	PEs
Plant	60	7.0	112	6.3
First Ratoon	38	7.8	102	6.8
Second Ratoon	15	5.0	60	6.8
Third Ratoon +	20	6.5	44	5.9

It is rather difficult to draw conclusions from these figures. We have too few cases of second and third ratoon crops on non-irrigated areas to warrant comparison with the plant crop. In the irrigated group, the slightly lower PEs for

third ratoon + crops is due to the fact that 26 of these 44 tests were at the Waipio substation where the PEs for all tests is 4.8 per cent.

At Waipio:

223 plots of plant cane have a PEs of 4.9 per cent
167 plots of 1st ratoon have a PEs of 3.9 per cent
169 plots of 2nd ratoon have a PEs of 3.6 per cent
206 plots of 3rd ratoon have a PEs of 4.6 per cent
352 plots of 4th ratoon have a PEs of 4.8 per cent
231 plots of 5th ratoon have a PEs of 5.6 per cent

At Pioneer:

928 plots of plant cane have a PEs of 6.3 per cent
1010 plots of 1st rtaoon cane have a PEs of 6.8 per cent
806 plots of 2nd ratoon cane have a PEs of 6.9 per cent
141 plots of 3rd ratoon cane have a PEs of 6.3 per cent

If the variability of ratoons at Waipio seems to decrease on the early ratoons, then the situation seems reversed at Pioneer. Hence no general assumption can be made from the data available.

(2) Although we have an insufficiency of data, from tests which have been repeated on the same plots through successive crops, to give us over-confidence in a feeling that the cane plant has a remarkable aptitude for adjusting its stand to the conditions it finds itself growing in, there is some indication that this may be the case, and that the variation that exists in our test areas does not materially change from crop to crop as a result of a change in stand.

In that number of repeated tests which our data included we found the following:

(a) The PEs of the first repetition greater than in the original test in 57 cases, and less than in the original test in 42 cases.

(b) The PEs of the second repetition greater than in the first repetition in 20 cases and less in 21 cases; greater than in the original test in 22 cases and less than the original in 19.

(c) The PEs of the third repetition greater than in second in 4 cases and less in 3; greater than the first repetition in 3 and less in 3 cases; greater than in the original test in 3 cases, and less than in the original in 3 cases also.

Individual plantation data show a similar tendency.

At Waipio, we have the following:

Twelve tests, repeated, show a higher PEs on the succeeding than on the original test; thirteen tests show a lower PEs after the original test.

At Pioneer, 32 tests show a higher PEs on ratoons than on plant, while 27 show up higher on plant than on ratoons.

At Koloa, 5 out of 10 tests which were repeated have a higher PEs in the original than in the succeeding crop.

(c) *How does the size of the individual plot affect the probable error of the experiment?*

We find advocates of small plots and advocates of large ones. Have our experimental data indicated what size of plot is best suited for accuracy?

The standard size plot for unirrigated cane has generally been accepted as one-tenth acre, while the conventional watercourse plot varying from slightly under to slightly over a tenth acre has been the unit used on irrigated lands. We find that 85 per cent of our tests have used these unit plot sizes, only 9 per cent having used a smaller and 6 per cent a greater size. Hence our data on this question are too meager for statistical study.

We have, however, enumerated below 5 cases where the data within each case are quite comparable and have a bearing on this question of plot size. These are offered as a matter of interest and for record.

Plantation	Field	Year	Exp. No.	No. of Plots	Plot Size	Total Test Area	PEs
(1) Paauhau	18	1921	10	32	.25 ac.	8 ac.	3.9
"	18	1921	11	18	.1 ac.	1.8 ac.	6.6
(2) Hakalau	10	1919	8	24	.1 ac.	2.4 ac.	5.0
"	10	1919	3B	36	.05 ac.	1.8 ac.	7.3
"	10	1919	7	48	.1 ac.	4.8 ac.	9.2
"	10	1919	9	72	.05 ac.	3.6 ac.	12.4
(3) Kilauea	37	1924	51	15	.07 ac.	1.1 ac.	8.2
"	37	1924	30	15	.1 ac.	1.5 ac.	12.7
"	37	1924	31	18	.1 ac.	1.8 ac.	14.5
"	37	1924	28	32	.1 ac.	3.2 ac.	10.7
(4) Pioneer	E2	1929	71	20	4 wc	80 wc	5.0
"	E2	1929	49	24	1 wc	24 wc	9.4
"	E2	1929	50	20	1 wc	20 wc	10.9
"	E2	1929	47	18	1 wc	18 wc	6.4
"	E2	1929	48	15	1 wc	15 wc	9.6

(5) At the Maui Agricultural Company the 10 tests which were studied showed a PEs of 4.8 per cent. Of these 10 tests, 4 used level ditch plots (area 1.0 + acres) and the PEs was 3.9 per cent; 6 used single watercourse plots and these had a PEs of 5.4 per cent.

(d) *What effect has the number of replications on the size of the PEs for our cane field tests?*

Theoretically, statistical measurements tell us that a reduction in error may be expected to occur in direct proportion to the square root of the number of samples taken. Because of the fact that when we increase the number of replications (samples) in our field tests, we must move into an increased area and hence possibly include new variations, this expected reduction in our experimental error does not always take place at any proportional rate.

Analysis of our complete data which concerns this question follows:

In 42 tests with 4 or less replications,	the PEs was 6.5 per cent	
In 68 tests with 5 replications,	the PEs was 6.7 per cent	—6.3 per cent
In 111 tests with 6 replications,	the PEs was 5.9 per cent	
In 80 tests with 7 replications,	the PEs was 6.4 per cent	
In 66 tests with 8 replications,	the PEs was 6.6 per cent	—6.9 per cent
In 17 tests with 9 replications,	the PEs was 6.8 per cent	
In 14 tests with 10 replications,	the PEs was 7.3 per cent	
In 53 tests with more than 10 replications,	the PEs was 7.7 per cent	

At Waipio:

8 tests with 4 or less replications had a PEs of 3.2 per cent
17 tests with 5 to 7 replications had a PEs of 4.3 per cent
9 tests with 8 to 10 replications had a PEs of 4.7 per cent
10 tests with more than 10 replications had a PEs of 6.4 per cent

At Pioneer:

23 tests with 5 replications had a PEs of 6.3 per cent
40 tests with 6 replications had a PEs of 6.6 per cent —6.4 per cent
29 tests with 7 replications had a PEs of 6.4 per cent
13 tests with 8 to 10 replications had a PEs of 6.1 per cent
9 tests with more than 10 replications had a PEs of 8.9 per cent

(e) *Does the size of the total experimental area affect the PEs?*

We have assumed that under the widely varying soil conditions existent in our fields, the variation between plots established therein would be increased as our total area was enlarged. Our complete data indicate that there is a tendency for this to happen.

130 tests, in which the total area was under 2 acres, had a PEs of 6.4 per cent.
193 tests, in which the total area was from 2 to 3 acres had a PEs of 6.4 per cent.
128 tests, in which the total area was over 3 acres had a PEs of 7.0 per cent.

At Pioneer:

38 tests, in which the total area was under 2 acres, had a PEs of 6.4 per cent.
69 tests, in which the total area was from 2 to 3 acres, had a PEs of 6.9 per cent.
9 tests, in which the total area was over 3 acres, had a PEs of 7.7 per cent.

At Koloa:

8 tests in which the total area was under 2 acres had a PEs of 6.4 per cent.
10 tests in which the total area was from 2 to 3 acres had a PEs of 8.5 per cent.
4 tests in which the total area was over 3 acres had a PEs of 11.7 per cent.

(f) *What is the relation between the total number of plots and the probable error of a single plot?*

138 tests with less than 20 plots per test show a PEs of 6.3 per cent.
212 tests with 20 to 29 plots per test show a PEs of 6.4 per cent.
55 tests with 30 to 39 plots per test show a PEs of 6.7 per cent.
32 tests with 40 to 52 plots per test show a PEs of 7.2 per cent.
14 tests with over 55 plots per test show a PEs of 9.0 per cent.

From this, it would appear that there is perhaps a slight increase in the variability within our test area as the number of plots is increased.

(g) *Is there any relationship between the number of variates or treatments in our test and the PEs?*

73 tests carrying 2 variates have a PEs of 6.6 per cent.
116 tests carrying 3 variates have a PEs of 6.3 per cent.
201 tests carrying 4 variates have a PEs of 6.5 per cent.
33 tests carrying 5 variates have a PEs of 7.0 per cent.
28 tests carrying 6 or more variates have a PEs of 8.6 per cent.

Hence, it would seem that the number of variates per test has little influence on the probable error of a single plot until our tests begin to carry six or more different treatments, when it appears that the increased number of variables has probably increased the total experimental area and hence widened the variability between plots therein.

(h) *What is the effect of the cane yield upon the PEs?*

The following table shows the frequencies with which the probable errors of single plots have occurred in fields of varying cane tonnages:

FREQUENCIES OF PEs (IN PER CENT) AS RELATED TO CANE TONNAGE

Av. Cane Tonnage	Under 3 Per cent.	3.1 to 5 Per cent.	5.1 to 7 Per cent.	7.1 to 9 Per cent.	9.1 to 11 Per cent	11.1 to 13 Per cent.	13.1 to 15 Per cent	Over 15 Per cent.	Total Tests.
20 to 40	3	4	27	24	13	11	9	6	97
40 to 60	2	32	46	36	24	6	0	4	150
60 to 80	3	53	44	18	7	5	1	0	131
80 to 100	6	24	20	2	6	0	0	0	58
100 to 120	3	11	8	1	0	0	0	0	23
Totals	17	124	145	81	50	22	10	10	459

From this table, it is quite apparent that the greater variations within our field tests, as indicated by the larger PEs per cent figures, are in the poorer producing areas, and that as our yields are increased the PEs tends materially to be improved.

Roughly figured, we note the following:

In 30-ton cane, only one-third of the tests have a PEs under 7 per cent, and less than one-tenth of them have a PEs under 5 per cent.

In 50-ton cane, about one-half of the tests have a PEs under 7 per cent, and one-fifth are under 5 per cent.

In 70-ton cane, three-fourths of the tests are under 7 per cent and two-fifths under 5 per cent.

In 90-ton cane, seven-eighths of the tests have errors attached to single plots of less than 7 per cent, and on one-half of the tests observed on fields producing at this rate, the PEs is under 5 per cent.

In 110-ton cane, practically no test has a PEs greater than 7 per cent. Sixty per cent of our tests on these areas of high yields carry errors of single plots which are under 5 per cent.

(i) *What is the effect of plant food upon the probable error of a single plot or areas receiving different kinds and amounts of food?*

This question aimed to find out whether the variation between plots in cane that was amply supplied with plant food was less than the variation occurring in areas where the supply of some food material might be scanty.

The results are summarized below. They indicate that well fed cane carries a lower PEs than cane which has less food. From which it is not unreasonable to believe that an ample supply of plant food will do much to offset the natural soil plant food deficiencies which are perhaps responsible for much of the variation between plots in our experimental areas.

EFFECT OF PLANT FOODS ON THE PEs OF A SERIES OF PLOTS RECEIVING SPECIFIC PLANT FOOD TREATMENTS

No. of Comparable Series	Treatments Compared	Number of Cases Showing		
		No Change in PEs (within .1 Per cent)	Lower PEs with Increased Food	Higher PEs with Increased Food
26	No Fertilizer vs. N[1]..........	1	23	2
67	N vs. NP....................	1	42	24
72	N vs. NK..................	2	34	36
69	N vs. NPK..................	2	39	28
65	NP vs. NPK..	1	24	40
67	NK vs. NPK................	1	36	30
5	PK vs. NPK.................	0	5	0
31	No P vs. P[2]..................	0	19	12
32	No K vs. K[2].................	1	20	11
48	Less than 100 lbs. N vs. 150 lbs. N[3]	1	35	12
70	150 lbs. N vs. 200 lbs. N......	3	33	34
55	200 lbs. N vs. 250 lbs. N......	0	26	29
50	250 lbs. N vs. 300 to 350 lbs. N	5	21	24
36	No P vs. 60 lbs. P............	1	20	15
22	60 lbs. P vs. 120 lbs. P.......	2	9	11
23	120 lbs. P vs. 180 to 200 lbs. P	..	13	10
21	200 lbs. P vs. 300 lbs. P......	..	8	13
39	No K vs. 60 lbs. K...........	..	19	20
25	60 lbs. K vs. 120 lbs. K.......	2	16	7
35	120 lbs. K vs. 180 lbs. K......	..	16	19
26	200 lbs. K vs. 300 lbs. K... ..	1	10	16

(j) *Is the PEs in our experimental fields influenced by the elevation of the area above sea level?*

The factors which complicate an answer to this question are too numerous to enable us to make use of the limited amount of data available. As a matter of interest, however, the tests which were conducted at Pioneer when arranged according to field elevation show the following:

27 tests conducted below 300′ elevation have a PEs of 5.7 per cent.
36 tests conducted between 300′ and 600′ elevation have a PEs of 7.0 per cent.
35 tests conducted between 600′ and 900′ elevation have a PEs of 6.6 per cent.
11 tests conducted above 900′ elevation have a PEs of 8.1 per cent.

[1] 150 lbs., [2] 250 lbs., [3] Amounts that follow are approximate.

A factor which greatly complicates any analysis of these figures from Pioneer, however, is that cane from the upper elevation fields is flumed from the plots before weighing, and the influence of this factor may be better understood from the following:

Thirty-nine tests in which cane was flumed before weighing show a PEs of 7.7 per cent; half of them carrying errors over 8 per cent. Against this, we have 76 tests which were loaded directly onto cars in the field, which have a PEs of 6.0 per cent, with only one-tenth of same having errors greater than 8 per cent.

(k) *Will an analysis of our PEs data assist us to locate our field tests so that introduced variates may have fair comparisons?*

The data in the following table should help us to answer this question, if we are right in assuming that a low PEs indicates a lack of extreme variability in our test area. Where several tests that have been harvested in the same locality carry a PEs below 7 per cent we have a fairly good indication that the natural conditions there are quite similar, and it should be a good place for our field experiment:

SOME PEs OF TESTS LOCATED IN SPECIFIC FIELDS

Plantation	Field	Total Tests	No. of Tests with PEs Per Cent Under 5	5–7	7–9	9–12	Over 12
Paauhau	18	2	1	1	..	..	..
"	4	2	..	2	..	..	..
Lihue	40	7	3	4	..	..	..
Makee	13	2	1	..	..	..	..
"	1	1	2		..	..	.
H. C. & S. Co.	D Co. 3	3	3	..	..	..	..
"	12	2	2	..	..	..	..
Maui Agr. Co.	61	2	2	..	..	..	..
Pioneer	32	12	7	3	2	..	.
"	B4	10	5	5	..	..	..
"	33	2	2	..	..	..	..
Honomu	6B	4	1	3	..	..	..
Waipio	V	8	8	.	..	..	..
"	B	3	3	..	..	..	..
Waialua	Gay	3	3	..	..	..	..
"	Mill	5	2	3	..	..	..
Koloa	52	6	4	1	1	..	..
Hamakua	19	4	..	1	2	1	..
Pioneer	B6L	12	1	3	4	4	..
"	LA7	11	2	3	1	5	..
"	E 2	8	1	2	1	4	.
Union	Kah 37	2	..	..	..	..	2
Hilo	10	5	..	1	2	1	1
Kilauea	25	2	..	..	..	.	2
Koloa	51	8	..	2	2	2	2

When several tests in a field show a particularly high PEs we must not be too quick to condemn such field for experimental work. The PEs is affected by factors other than soil variation, and a careful analysis of any test carrying a high

probable error will frequently reveal discrepancies or mistakes which are not due to chance soil variation alone, and which may be rectified so that the true variability of the area in question and its adaptability for field testing can be ascertained.

SUMMARY

A study of the probable error of a single plot for sugar cane field experiments was made from the yields of 12,271 plots harvested in 451 field tests conducted by the Station's agricultural department throughout the Islands during the last ten years.

The probable error for a single plot was found to be 6.6 per cent, with no significant difference between the error from irrigated and non-irrigated areas.

The data warrant no general assumption that the probable error is influenced by the age of the field since last planting. This issue is evidently purely a localized one.

Insufficient data make it impossible to determine the relation between size of plot and size of error. There is some indication that plots somewhat larger than those ordinarily used may carry a lower probable error.

Due to the environmental variability that exists, an increase in the number of replications has not resulted in a proportionate lowering of the probable error. An increase in the size of the total experimental area has generally tended to increase this error.

The number of variates in a test, *per se*, have little if any effect upon the PEs.

The size of the probable error seems to be quite definitely affected by the cane tonnages grown. With high cane yields, we find a considerably greater number of tests carrying low probable errors and few with high errors; on poorer yielding areas, the proportion of tests with high errors is considerably greater.

A relationship is noted between the PEs and the available plant food supply. Plots receiving nitrogen at less than 100 pounds per acre are quite apt to carry larger probable errors than plots of more amply fed cane.

The effect of elevation upon the PEs was so complicated with other factors that no conclusions from the data are justified, but there is some indication that the PEs increases with altitude, probably due to decreasing cane yields.

The study quite definitely located specific fields that are especially adaptable for accurate field test work, as well as it pointed out areas which are unsuitable and upon which the installation of a field experiment would be a questionable procedure.

Some Basic Statistical Data for the Interpretation of Field Experiments at Ewa Plantation Company

By J D Bond

Interest in the use of statistical methods as an aid in the interpretation of field experiments has been recently stimulated through the visit of Dr H H Love. Emphasis has been placed particularly on the probable error of a single plot as a prime factor in the expected limits of accuracy of field tests. In order to determine the normal probable error of a single plot under local conditions, as well as the normal curves of error concerned, a portion of the accumulated experimental data of the Ewa Plantation Company over eight crops has been reviewed. These data are derived only from experiments dealing with problems in fertilization and include in the neighborhood of 5000 harvested plots. No attempt has been made in this study to differentiate between the character of the experiment locations as evidenced by plot variation, so that all conditions are represented. We may thus consider the summaries as representative of average conditions.

The experiments concerned have been conducted according to a standard practice which need not be discussed here. In the matter of contiguous plot comparisons, it is our practice in a layout involving only two treatments which are alternated, to compare a treatment plot with the adjacent checks individually. Thus, in a layout as represented below:

Level Ditch

1A	2X	3A	4X	5A	6X

Level Ditch

plot 3A would be compared both with 2X and 4X, and plot 5A with 4X and 6X. Comparisons involving plots 3A and 5A will then total 4. Where check and treatment are not alternated, only one comparison is, of course, available. No comparisons are attempted between plots located in different level ditch areas.

The data have been considered both from the standpoint of the variation about the treatment mean in per cent of the means, and from the standpoint of the variation about mean differences, in original units, from contiguous plot comparisons. The data in both instances have been grouped in classes as indicated in Tables I and II under the heading "Actual Data—Per Cent Frequency." Inasmuch as no omissions were originally attempted in building up these frequency data, it was found advisable to subquently omit from the table those cases, which, from the first completed tabulation or, later, from the partially built frequency variation, extended beyond the initial class showing zero frequency. This was, of course, essential in developing such continuous data as would permit the fitting of the normal curve of error. The effect of these omissions on the final arrangement was very small indeed, the number being usually less than 1 per cent of the total number of individuals. The cases omitted represented such extremes as would

without doubt be omitted in any case in the interpretation of the results of any one experiment.

After these omissions had been effected, the data were re-worked into the final form shown in Tables I and II. It was found, however, that the normal curves of error developed from the calculated standard deviations of the actual data of Tables I and II gave very poor fits, due, presumably, to the preponderance of large variations at the tails of the frequency curves. We proceeded then to determine the modulus of a normal curve of error for every point of Tables I and II including 1 per cent or more of the total number of individuals. Since for every point there are two curves of error which will satisfy the requirements, the modulus of that curve of error giving the standard deviation nearer the standard deviation of the original data, was taken. No corrections were made in the original data for the slight errors involved in grouping or for taking the mean at precisely the mid-point.

The type formula for the normal curve of error is:

$$y = \frac{}{C\sqrt{\pi}} e^{\frac{-(X - \text{Mean})^2}{}}$$

where Y is the proportional frequency of the variation X; and C is the curve characteristic or modulus.

The arithmetical average of the moduli determined for each point representing 1 per cent or more of the total individuals, then gave us the most probable modulus or the most probable normal curve of error under our conditions.

In two instances in this study, the point considered was found to lie slightly outside the range represented by the normal curve of error at the specific value of X. These points, in so far as the determination of the modulus was concerned were omitted from consideration.

Finally, the normal curves of error for cane, quality ratio, sugar, Brix and purity for both the variation about the mean in per cent of the mean; and for the variation about mean differences in original units from the comparisons of contiguous plots, were plotted in comparison with the actual frequency data and are shown in Figs. 1 to 10. From these data we have the following probable errors of a single plot:

PROBABLE ERROR OF A SINGLE PLOT

	Variation in Per Cent		Variation About Mean Diff.	
	Actual Data	Fitted Curve	Actual Data	Fitted Curve
Cane	±5.68	±4.80	±4.54	±4.09
Q.R.	3.26	2.92	0.27	0.23
Sugar	5.36	4.62	0.60	0.52
Brix	2.00	1.89	0.34	0.29
Purity	0.97	0.83	0.70	0.65

It is at once evident that the probable errors of a single plot calculated from the fitted curves are consistently lower than those obtained from the actual frequency distribution. Inspection of the calculations and curves indicates that this is largely due to the greater frequencies of the larger deviations found in the actual

data. The squaring of these deviations in the process of calculating the probable error causes them to be of appreciable influence when associated with the higher frequency values. Either, then, the normal law of error does not strictly apply to our conditions, or the relatively large frequencies of the variations at the tails of the curve are due to environmental influences which may be considered as beyond the effect of chance. Knowing the effect of straight ditches, outside plots and differences in soil fertility on plot yields, it seems logical to conclude that the discrepancy is due largely to unusual environmental influences. If we accept this assumption, then the elaboration of a system of plot omissions is in order.

The suggestion that all plots be omitted, which, from the normal curve of error, can be expected to occur only once in a thousand trials, or that this limit be three times the value of the standard deviation, seems too inclusive. Applying these suggestions to the normal curve of error for the cane variations about mean differences, from contiguous plot comparisons (Fig. 6), we find that the limits become $\pm$ 19.9 and $\pm$ 18.2 tons of cane respectively. Practically, this virtually includes the entire range of the normal curve of error and when applied to a test dealing with a small number of plots, is of rather doubtful value.

From the normal curve of error, the range within which n — 1 plots can be expected to occur or the area under the curve represented by $\frac{n-1}{n}$ of the total, is quite definite. However, the nth plot may be expected to occur at any point between the limits of the area $\frac{n-1}{n}$ to, theoretically, infinity or under practical conditions let us say, from Fig. 6, $\pm$ 20 tons of cane. Obviously, our point of omission must lie somewhere within this lower range and that point is suggested which, in view of the discrepancies noted above between the actual frequency data and the fitted curves, we may term the probable error of the nth plot. In other words, we may expect from the fitted normal curve of error, that one plot will lie below this specified point once in every two experiments of n plots each. This point is represented by the area $\frac{2n-1}{2n}$ under the normal curve of error. Applying this, for example, to experiments dealing with ten contiguous plot comparisons, we find, from the values of the probability integral and Fig. 6, that the point of omission is $\pm$ 11.9 tons of cane.

During the compilation of the data summarized in Tables I and II, it was noted that the extreme limits of variation were progressively extended, in so far as continuous data were concerned, as the number of plots considered became greater and greater. This is of course to be expected but is some indication that conditions represented by normal curves of error which refer to and are derived from very large numbers of plots or plot comparisons, cannot be indiscriminately applied to single tests involving a small number of individuals.

In Table III, the suggested points of omission for the ten normal curves of error presented in this report, have been calculated for tests involving 2 to 30 individuals. In the application of this table, omissions are to be made progressively and one at a time, omitting the greatest variant at each step until all cases are to be found within the limits of Table III. After each omission, the limits of omission change in accordance with the smaller number of individuals remaining.

We have applied the omissions of Table III to our experimental data at hand dealing with contiguous plot comparisons in cane only and this is summarized in Table IV. The number of plots per test (n) after omissions has been carried only up to the point where at least ten tests are available. It is of note that the average number of omissions per test for each group fluctuates about one and averages over the whole almost exactly one. This is not at all excessive and is probably at least approximated in actual work where the omissions are made as a matter of individual judgment.

The "mean standard deviation" of Table IV is the arithmetical average of the standard deviations of the individual tests, while the "standard deviation of distribution" is that derived by building up individual plot variations so as to form the frequency curve for the conditions given. The "standard deviation of the standard deviation" was obtained by the usual procedure dealing with positive values of the standard deviation only. These data are quite erratic and of doubtful value for purposes of generalization.

An empirical formula fitted to the values of the mean standard deviation gives:

$$\text{Mean } \delta = \delta N \left(\frac{n-1}{n}\right)^{\sqrt{2}} = 0.06 \left(\frac{n-1}{n}\right)^{1.41}$$

where δN is the standard deviation of the normal curve of error concerned.
n is the number of plots per test after omissions.

When the number of plots per test becomes infinite, the average standard deviation must of course be equal to that of the normal curve of error.

From this empirical formula, the mean standard deviation to be expected from contiguous plot comparisons has been calculated (Table V) for numbers of comparisons per test, after omissions, ranging from 2 to 30. Applying Student's method with odds of 30 : 1 to these data, gives the limits of significance according to the number of comparisons per test for the average experiment (Table VI). The data of Table VI can be considered only as a guide to the laying out of experiments. It is particularly interesting to note that after the number of comparisons per test exceeds about fourteen, appreciably greater accuracy can be obtained only at the expense of many more plots scarcely commensurate with the increased accuracy to be obtained.

In the interpretation of experimental data, it is proposed to use Student's method after the omissions have been made as indicated. Tests of two plot comparisons only, are of doubtful value under any conditions since the standard deviation must be directly equal to the variation. In other words, there is no opportunity for the variation to approximate the distribution of the normal curve of error. In the data at hand on cane comparisons, of the twenty-four tests of two comparisons each, nine are found below a standard deviation of one and four below 0.5.

It must be remembered that Table VI refers to average conditions. Experiment locations can be expected to occur both of smaller and of greater variation, the smaller variation locations affording appreciably higher accuracy than indicated in Table VI. It is then obviously possible through the continued harvests of experiments to locate areas suitable to a relatively high degree of accuracy. Such areas

will then be devoted to problems in which a small probable error is essential; others to such problems as may be determined by greater limits of error; and still others which are not suitable for experimental purposes at all. The determination of the location-variation may be obtained by the use of blank tests, though from a practical plantation standpoint, it would appear most suitable to carry a definite test on the area in question. The variation can then be determined either from the consideration of the checks only or from the variation of the differences of contiguous plot comparisons about the mean differences. Such a selection of areas has been followed in the past and apparently has shown good results, though not attempted in a systematic way.

The results of all experiments are reported individually on the following form:

EWA PLANTATION CO.

KIND OF EXPERIMENT.......................... EXPERIMENT NO...............
Field............. Crop....................... Plant or Ratoon.......................
Crop Began...................... Crop Harvested......................
Cane Age....................... Area..............................

SUMMARY OF HARVESTING RESULTS

Treatment	YIELD PER ACRE: Arithmetical Average				
	Cane.	Q.R.	Sugar.	Brix.	Purity.
....	....	....	....	....	....
....	....	....	....	....	....
Gain or Loss for........................	....	....	....	....	....
Per Cent Gain or Loss for.................	....	....	....	....	....

PLOT TO PLOT COMPARISON

	Total	For	Same	For	Odds	Diff. Student's Method
Cane	....	....	....	....	....	....
Quality Ratio	....	....	....	....	....	....
Sugar	....	....	....	....	....	....
Brix	....	....	....	....	....	....
Purity	....	....	....	....	....	....

Details of Treatments:
Interpretation:

Under the heading "Yield Per Acre", the arithmetical treatment-averages are entered after omitting according to the data of Table III under "Per Cent of Means." Percentages are then expressed on the basis of the check treatment or, in case of doubt, on that treatment most closely approximating the plantation practice of the current crop.

Under "Plot to Plot Comparison," entries under the column "same" are determined by the probable error of the mean difference as determined from the fitted normal curves of error of Figs. 6 to 10, inclusive, by the formula $\text{P.E.}_m = \dfrac{\text{P.E.}_s}{\sqrt{n}}$.
Plot comparisons greater or less than the probable error of the mean are entered in

the other two columns according to whether the differences indicate the treatment or the check as the more productive.

Summary

1. Normal curves of error have been fitted to the data obtained from about 5000 harvested experimental plots of watercourse size Variation about the means in per cent of the mean and variation of contiguous plot comparison differences about the mean difference, have been considered under cane, quality ratio, sugar, Brix and purity

2. A table of omissions has been calculated based on the normal curves of error and the area $\frac{2n-1}{2n}$ under the curves, where n is the number of plots

3. This table of omissions has been applied to the data at hand and indicates an average omission of one plot per test This is not excessive.

4. From the mean standard deviations of tests involving two to fifteen individuals, an empirical formula has been developed in relation to the normal curve of error, giving the mean standard deviation to be expected from tests of n plots.

5. From the calculated mean standard deviations and Student's method, using odds of 30 : 1, mean limits of significance have been calculated.

6. A form and procedure for the summary of experiments has been outlined.

TABLE I

Normal Curves of Error From Harvested Experiment Plots—Variation About Means in Per Cent of Means

Class	Actual Data—Per Cent Frequency					Calculated from Curves—Per Cent Frequency				
Value	Cane	Q.R.	Sugar	Brix	Purity	Cane	Q.R.	Sugar	Brix	Purity
67.5			0.04							
68.5			0.11							
69.5			0.02							
70.5			0.02							
71.5	0.09		0.02							
72.5	0.09		0.13							
73.5	0.11		0.22							
74.5	0.09		0.09							
75.5	0.07		0.11							
76.5	0.15		0.13							
77.5	0.15		0.16							
78.5	0.20		0.27							
79.5	0.44		0.18			0.09		0.07		
80.5	0.36		0.16			0.13		0.10		
81.5	0.38	0.02	0.27			0.19		0.15		
82.5	0.49	0.04	0.38			0.27		0.22		
83.5	0.65	0.05	0.47			0.38		0.32		
84.5	0.71	0.09	0.52			0.52		0.45		
85.5	0.85	0.11	0.70			0.70		0.62		
86.5	0.98	0.15	0.58			0.93		0.84		
87.5	1.25	0.18	1.14	0.05		1.20	0.15	1.10		
88.5	1.38	0.40	1.07	0.07		1.52	0.27	1.42		
89.5	1.49	0.44	1.41	0.11		1.89	0.49	1.80		
90.5	1.87	1.03	1.63	0.22	0.02	2.30	0.83	2.23	0.05	
91.5	2.69	1.62	1.88	0.34	0.07	2.75	1.34	2.70	0.15	
92.5	2.87	2.16	3.20	0.78	0.05	3.22	2.05	3.20	0.40	
93.5	3.72	2.49	3.27	1.12	0.11	3.70	2.98	3.71	0.97	
94.5	4.17	3.90	3.94	2.18	0.18	4.16	4.11	4.20	2.09	

TABLE I (Continued)

Normal Curves of Error From Harvested Experiment Plots—Variation About Means in Per Cent of Means

Class	Actual Data—Per Cent Frequency					Calculated from Curves—Per Cent Frequency				
Value	Cane	Q.R.	Sugar	Brix	Purity	Cane	Q.R.	Sugar	Brix	Purity
95.5	3.90	5.43	4.55	3.75	0.71	4.59	5.37	4.69	3.93	0.04
96.5	5.14	6.79	5.19	5.22	1.23	4.97	6.65	5.11	6.54	0.59
97.5	5.48	8.58	5.95	8.38	4.50	5.27	7.80	5.45	9.56	1.54
98.5	6.02	8.80	6.13	11.79	12.88	5.49	8.68	5.69	12.32	15.46
99.5	5.35	9.84	6.09	15.09	27.92	5.60	9.16	5.81	13.99	29.75
100.5	5.68	9.75	6.29	14.82	32.02	5.60	9.16	5.81	13.99	29.75
101.5	5.53	8.10	5.93	13.67	14.33	5.49	8.68	5.69	12.32	15.46
102.5	5.08	6.73	6.13	8.85	4.08	5.27	7.80	5.45	9.56	1.54
103.5	4.36	5.61	5.04	5.86	1.51	4.97	6.65	5.11	6.54	0.59
104.5	4.32	4.14	4.25	3.57	0.27	4.59	5.37	4.69	3.93	0.04
105.5	3.52	3.19	3.79	1.83	0.11	4.16	4.11	4.20	2.09	
106.5	3.01	2.58	3.05	1.03		3.70	2.98	3.71	0.97	
107.5	2.74	2.20	2.78	0.63		3.22	2.05	3.20	0.40	
108.5	2.16	1.45	2.20	0.31		2.75	1.34	2.70	0.15	
109.5	1.91	1.18	1.53	0.13		2.30	0.83	2.23	0.05	
110.5	1.81	0.76	1.34	0.09		1.89	0.49	1.80		
111.5	1.52	0.60	1.52	0.09		1.52	0.27	1.42		
112.5	1.13	0.33	1.08			1.20	0.15	1.10		
113.5	0.80	0.29	0.72			0.93		0.84		
114.5	0.69	0.15	0.60			0.70		0.62		
115.5	0.60	0.20	0.51			0.52		0.45		
116.5	0.56	0.13	0.36			0.38		0.32		
117.5	0.45	0.13	0.45			0.27		0.22		
118.5	0.64	0.18	0.38			0.19		0.15		

TABLE I (Continued)

Normal Curves of Error From Harvested Experiment Plots—Variation About Means in Per Cent of Means

Class Value	Actual Data—Per Cent Frequency Cane	Q.R.	Sugar	Brix	Purity	Calculated from Curves—Per Cent Frequency Cane	Q.R.	Sugar	Brix	Purity
119.5	0.40	0.09	0.23			0.13		0.10		
120.5	0.42	0.02	0.34			0.09		0.07		
121.5	0.25		0.16							
122.5	0.16		0.16							
123.5	0.18		0.04							
124.5	0.20		0.13							
125.5	0.09		0.13							
126.5	0.16		0.13							
127.5	0.02		0.07							
128.5	0.11		0.11							
129.5	0.07		0.07							
130.5	0.09		0.07							
131.5	0.04		0.07							
132.5	0.04		0.04							
Total Number	5511	5509	5534	5514	5512					
St. Deviation	±8.42	±4.83	±7.94	±2.96	±1.44					
P.E.s	±5.68	±3.26	±5.36	±2.00	±0.97					

TABLE II

Normal Curves of Error for Cane
Variation in Tons Cane Per Acre About Mean Differences From Contiguous Plot Comparisons

Per Cent Frequency

Class Value	Actual Data	Calculated
—22.5	0.02	
—21.5	0.02	
—20.5	0.02	
—19.5	0.02	
—18.5	0.36	0.06
—17.5	0.29	0.10
—16.5	0.14	0.16
—15.5	0.74	0.25
—14.5	0.74	0.38
—13.5	0.93	0.55
—12.5	0.97	0.78
—11.5	1.24	1.09
—10.5	1.58	1.47
— 9.5	1.75	1.93
— 8.5	2.13	2.46
— 7.5	3.16	3.06
— 6.5	3.31	3.71
— 5.5	4.05	4.36
— 4.5	4.11	5.00
— 3.5	5.08	5.57
— 2.5	6.34	6.05
— 1.5	5.84	6.38
— 0.5	6.01	6.57
0.5	6.11	6.57
1.5	6.19	6.38
2.5	6.13	6.05
3.5	5.60	5.57
4.5	4.72	5.00
5.5	4.40	4.36
6.5	3.43	3.71
7.5	3.10	3.06
8.5	2.04	2.46
9.5	1.79	1.93
10.5	1.75	1.47
11.5	1.24	1.09
12.5	0.88	0.78
13.5	1.10	0.55
14.5	0.63	0.38
15.5	0.42	0.25
16.5	0.40	0.16
17.5	0.23	0.10
18.5	0.34	0.06
19.5	0.04	
Total Number	4746	
St. Deviation	±6.73	
P.E. s	±4.54	

TABLE II (Continued)

Normal Curves of Error. Variation in Original Units About Mean Differences From Contiguous Plot Comparisons

Class Value	Actual Data—Per Cent Frequency Q.R.	Sugar	Brix	Purity	Calculated From Curves—Per Cent Frequency Q.R.	Sugar	Brix	Purity
—3.55		0.04						
—3.45		0.06						
—3.35		0.08		0.04				
—3.25		0.10		0.06				
—3.15		0.04		0.08				
—3.05		0.14		0.10				
—2.95		0.06		0.17				
—2.85		0.06		0.17				
—2.75		0.08		0.29				
—2.65		0.10		0.17				0.09
—2.55		0.12		0.17				0.12
—2.45		0.04		0.33				0.16
—2.35		0.21		0.23				0.21
—2.25		0.23		0.46		0.07		0.27
—2.15		0.23		0.44		0.11		0.34
—2.05		0.25		0.59		0.15		0.43
—1.95		0.57	0.04	0.54		0.21		0.53
—1.85		0.53	0.14	0.69		0.29		0.65
—1.75	0.04	0.49	0.02	0.82		0.39		0.79
—1.65	0.04	0.57	0.23	1.19		0.52		0.95
—1.55	0.10	0.66	0.08	1.30		0.69		1.13
—1.45	0.13	0.96	0.23	1.15		0.88		1.33
—1.35	0.23	0.76	0.29	1.59		1.12	0.08	1.55
—1.25	0.19	1.17	0.33	1.44		1.39	0.15	1.78
—1.15	0.25	1.58	0.45	1.90	0.04	1.70	0.28	2.03
—1.05	0.40	1.93	0.66	1.69	0.11	2.05	0.50	2.29
—0.95	0.58	2.01	0.77	1.92	0.25	2.42	0.85	2.55
—0.85	0.71	2.50	1.70	2.74	0.53	2.82	1.36	2.81
—0.75	1.42	2.87	1.90	3.03	1.06	3.23	2.08	3.06
—0.65	1.84	3.47	2.73	3.26	1.92	3.63	3.01	3.30
—0.55	2.55	3.90	3.85	3.58	3.21	4.01	4.13	3.52
—0.45	4.26	4.33	5.28	3.55	4.91	4.37	5.37	3.72
—0.35	5.87	4.90	6.71	3.64	6.92	4.67	6.63	3.88
—0.25	9.17	4.70	7.60	4.31	8.93	4.91	7.77	4.01
—0.15	10.98	5.07	9.15	4.06	10.59	5.08	8.64	4.10
—0.05	10.57	4.74	9.22	3.97	11.53	5.17	9.10	4.15
0.05	12.59	4.97	9.03	4.25	11.53	5.17	9.10	4.15
0.15	11.00	5.48	8.80	4.25	10.59	5.08	8.64	4.10
0.25	8.12	4.82	7.24	4.27	8.93	4.91	7.77	4.01
0.35	6.06	4.82	6.06	3.22	6.92	4.67	6.63	3.88
0.45	3.82	4.60	4.72	4.12	4.91	4.37	5.37	3.72
0.55	3.13	3.47	4.02	3.55	3.21	4.01	4.13	3.52
0.65	2.00	3.28	2.84	3.03	1.92	3.63	3.01	3.30
0.75	1.25	3.32	1.53	2.59	1.06	3.23	2.08	3.06
0.85	0.88	2.28	1.41	2.53	0.53	2.82	1.36	2.81
0.95	0.58	2.32	1.18	2.66	0.25	2.42	0.85	2.55
1.05	0.33	1.66	0.79	2.11	0.11	2.05	0.50	2.29
1.15	0.31	1.58	0.52	1.86	0.04	1.70	0.28	2.03
1.25	0.21	1.50	0.43	1.46		1.39	0.15	1.78
1.35	0.04	1.13	0.35	1.57		1.12	0.08	1.55

TABLE II (Continued)

Normal Curves of Error. Variation in Original Units About Mean Differences From Contiguous Plot Comparisons

Class Value	Actual Data—Per Cent Frequency Q.R.	Sugar	Brix	Purity	Calculated From Curves—Per Cent Frequency Q.R.	Sugar	Brix	Purity
1.45	0.06	0.86	0.21	1.46		0.88		1.33
1.55	0.17	0.59	0.21	1.42		0.69		1.13
1.65	0.02	0.68	0.10	0.84		0.52		0.95
1.75	0.04	0.41	0.08	0.90		0.39		0.79
1.85	0.04	0.49	0.06	0.63		0.29		0.65
1.95		0.33	0.04	0.54		0.21		0.53
2.05		0.25		0.52		0.15		0.43
2.15		0.33		0.40		0.11		0.34
2.25		0.14		0.27		0.07		0.27
2.35		0.14		0.36				0.21
2.45		0.14		0.25				0.16
2.55		0.14		0.33				0.12
2.65		0.08		0.31				0.09
2.75		0.18		0.21				
2.85		0.04		0.06				
2.95		0.10		0.10				
3.05		0.06		0.06				
3.15		0.04		0.04				
3.25		0.06		0.06				
3.35		0.04		0.06				
3.45		0.04						
3.55		0.04						
Total Number	4789	4874	4831	4782				
St. Deviation	±0.40	±0.90	±0.50	±1.04				
P.E.s	±0.27	±0.60	±0.34	±0.70				

TABLE III

Suggested Omissions—Variations About Mean Differences in Original Units; and About Treatment Means in Per Cent

No.	Cane Tons	Q.R.	Sugar	Brix	Purity	n	Per Cent of Means: Cane %	Q.R.	Sugar	Brix	Purity	n
2	±6.97	±0.39	±0.89	±0.50	±1.11	2	±8.16	±4.98	±7.88	±3.23	±1.42	2
3	8.38	0.47	1.07	0.60	1.33	3	9.84	5.98	9.48	3.88	1.71	3
4	9.30	0.53	1.18	0.67	1.48	4	10.91	6.64	10.51	4.31	1.90	4
5	9.97	0.56	1.27	0.72	1.58	5	11.70	7.12	11.27	4.62	2.04	5
6	10.49	0.59	1.33	0.75	1.67	6	12.32	7.49	11.87	4.86	2.14	6
7	10.92	0.62	1.39	0.79	1.73	7	12.82	7.80	12.35	5.06	2.23	7
8	11.29	0.64	1.44	0.81	1.79	8	13.25	8.06	12.76	5.23	2.31	8
9	11.60	0.66	1.48	0.83	1.84	9	13.62	8.28	13.12	5.37	2.37	9
10	11.88	0.67	1.51	0.85	1.88	10	13.94	8.45	13.43	5.50	2.43	10
11	12.12	0.68	1.54	0.87	1.92	11	14.23	8.66	13.71	5.62	2.48	11
12	12.34	0.70	1.57	0.89	1.96	12	14.49	8.81	13.96	5.72	2.52	12
13	12.54	0.71	1.60	0.90	1.99	13	14.72	8.96	14.18	5.81	2.56	13
14	12.73	0.72	1.62	0.91	2.02	14	14.94	9.09	14.39	5.90	2.60	14
15	12.90	0.73	1.64	0.93	2.05	15	15.14	9.21	14.58	5.97	2.63	15
16	13.05	0.74	1.66	0.94	2.07	16	15.32	9.32	14.76	6.05	2.67	16
17	13.20	0.75	1.68	0.95	2.09	17	15.49	9.42	14.92	6.11	2.70	17
18	13.33	0.75	1.70	0.96	2.12	18	15.65	9.52	15.08	6.18	2.72	18
19	13.46	0.76	1.71	0.97	2.14	19	15.80	9.61	15.22	6.24	2.75	19
20	13.58	0.77	1.73	0.98	2.16	20	15.94	9.70	15.36	6.29	2.77	20
21	13.70	0.77	1.74	0.98	2.17	21	16.08	9.78	15.49	6.34	2.80	21
22	13.80	0.78	1.76	0.99	2.19	22	16.20	9.86	15.61	6.39	2.82	22
23	13.91	0.79	1.77	1.00	2.21	23	16.33	9.93	15.72	6.44	2.84	23
24	14.00	0.79	1.78	1.01	2.22	24	16.44	10.00	15.83	6.49	2.86	24
25	14.10	0.80	1.79	1.01	2.24	25	16.55	10.07	15.94	6.53	2.88	25
26	14.19	0.80	1.80	1.02	2.25	26	16.65	10.13	16.04	6.57	2.90	26
27	14.27	0.81	1.82	1.03	2.26	27	16.75	10.19	16.14	6.61	2.91	27
28	14.35	0.81	1.83	1.03	2.28	28	16.85	10.25	16.23	6.65	2.93	28
29	14.43	0.82	1.84	1.04	2.29	29	16.94	10.31	16.32	6.69	2.95	29
30	14.51	0.82	1.85	1.04	2.30	30	17.03	10.36	16.40	6.72	2.96	30

TABLE IV

Contiguous Plot Comparisons—Cane Only. Application of Table of Omissions and Data on Standard Deviations

No. of Compar-isons Per Test	Av. No. of Comparisons Omitted Per Test	No. of Tests	Mean St. Dev.	St. Dev. of Distri bution	Calculated Mean St. Dev. (Formula)	St. Dev. of St. Deviation
2	1.40	24	1.95	2.50	2.28	1.56
3	0.87	39	3.98	4.11	3.12	1.91
4	1.09	57	1.26	4.48	4.04	1.39
5	1.11	75	4.21	4.16	4.42	1.46
6	0.59	69	4.28	4.41	4.69	1.22
7	0.94	62	4.63	1.77	1.88	1.18
8	1.04	50	5.09	5.22	5.02	1.18
9	1.30	40	4.93	5.04	5.12	1.07
10	0.96	24	5.44	5.52	5.22	0.96
11	1.61	18	5.48	5.59	5.30	1.10
12	0.58	12	5.11	5.19	5.36	0.89
13	1.33	18	5.41	5.57	5.11	1.32
14	1.15	26	5.50	5.61	5.16	1.22
15	0.80	10	5.69	5.77	5.50	0.91
Total & Averages	1.01	524				

* After omissions.

Formula

Mean St. Dev. $\sqrt{\left(\frac{n-1}{n}\right)}\ 1.41$

TABLE V

Mean Standard Deviation From Formula

No. of Comparisons Per Test	Cane	Q.R.	Sugar	Brix	Purity
2	2.28	0.129	0.290	0.164	0.362
3	3.42	0.193	0.435	0.246	0.543
4	4.04	0.228	0.514	0.291	0.641
5	4.42	0.250	0.563	0.318	0.702
6	4.69	0.264	0.596	0.337	0.744
7	4.88	0.275	0.620	0.351	0.774
8	5.02	0.283	0.639	0.361	0.797
9	5.12	0.289	0.651	0.368	0.813
10	5.22	0.295	0.665	0.376	0.829
11	5.30	0.299	0.674	0.381	0.841
12	5.36	0.303	0.682	0.386	0.851
13	5.41	0.306	0.689	0.389	0.859
14	5.46	0.308	0.695	0.393	0.867
15	5.50	0.310	0.700	0.396	0.873
16	5.53	0.312	0.704	0.398	0.878
17	5.56	0.314	0.708	0.400	0.883
18	5.59	0.316	0.711	0.402	0.888
19	5.62	0.317	0.714	0.404	0.891
20	5.64	0.318	0.717	0.406	0.895
21	5.66	0.319	0.720	0.407	0.898
22	5.68	0.320	0.722	0.408	0.901
23	5.69	0.321	0.724	0.409	0.904
24	5.71	0.322	0.726	0.411	0.906
25	5.72	0.323	0.728	0.412	0.908
26	5.73	0.324	0.730	0.413	0.910
27	5.75	0.324	0.731	0.413	0.912
28	5.76	0.325	0.732	0.414	0.914
29	5.77	0.325	0.734	0.415	0.916
30	5.78	0.326	0.735	0.416	0.917

TABLE VI

Limits of Significance by Student's Method (Odds 30 : 1)
Using Mean Standard Deviation

No. of Comparisons Per Test	Cane	Q.R.	Sugar	Brix	Purity
2	22.4	1.27	2.85	1.61	3.56
3	9.0	0.51	1.15	0.65	1.41
4	6.7	0.38	0.85	0.48	1.06
5	5.6	0.32	0.71	0.40	0.89
6	5.0	0.28	0.63	0.36	0.79
7	4.5	0.25	0.57	0.32	0.72
8	4.2	0.23	0.53	0.30	0.66
9	3.9	0.22	0.49	0.28	0.62
10	3.7	0.21	0.47	0.26	0.58
11	3.5	0.20	0.44	0.25	0.56
12	3.3	0.19	0.42	0.24	0.53
13	3.2	0.18	0.41	0.23	0.51
14	3.1	0.17	0.39	0.22	0.49
15	3.0	0.17	0.38	0.21	0.47
16	2.9	0.16	0.36	0.21	0.45
17	2.8	0.16	0.35	0.20	0.44
18	2.7	0.15	0.34	0.19	0.43
19	2.6	0.15	0.33	0.19	0.42
20	2.6	0.15	0.33	0.19	0.41
21	2.5	0.14	0.32	0.18	0.40
22	2.4	0.14	0.31	0.18	0.39
23	2.4	0.13	0.30	0.17	0.38
24	2.3	0.13	0.29	0.17	0.37
25	2.3	0.13	0.29	0.16	0.36
26	2.2	0.13	0.28	0.16	0.35
27	2.2	0.12	0.28	0.16	0.34
28	2.1	0.12	0.27	0.16	0.34
29	2.1	0.12	0.27	0.15	0.34
30	2.1	0.12	0.27	0.15	0.33

TABLE VII

Limits (Inclusive) for Plot to Plot Comparison
Summaries Under "Same"

Number	Cane	Q.R.	Sugar	Brix	Purity
2	±2.89	±0.16	±0.37	±0.21	±0.46
3	2.36	0.13	0.30	0.17	0.37
4	2.04	0.12	0.26	0.15	0.32
5	1.83	0.10	0.23	0.13	0.29
6	1.67	0.09	0.21	0.12	0.26
7	1.54	0.09	0.20	0.11	0.25
8	1.44	0.08	0.18	0.10	0.23
9	1.36	0.08	0.17	0.10	0.22
10	1.29	0.07	0.16	0.09	0.21
11	1.23	0.07	0.16	0.09	0.20
12	1.18	0.07	0.15	0.08	0.19
13	1.13	0.06	0.14	0.08	0.18
14	1.09	0.06	0.14	0.08	0.17
15	1.06	0.06	0.13	0.08	0.17
16	1.02	0.06	0.13	0.07	0.16
17	0.99	0.06	0.13	0.07	0.16
18	0.96	0.05	0.12	0.07	0.15
19	0.94	0.05	0.12	0.07	0.15
20	0.91	0.05	0.12	0.07	0.15
21	0.89	0.05	0.11	0.06	0.14
22	0.87	0.05	0.11	0.06	0.14
23	0.85	0.05	0.11	0.06	0.14
24	0.83	0.05	0.11	0.06	0.13
25	0.82	0.05	0.10	0.06	0.13
26	0.80	0.05	0.10	0.06	0.13
27	0.79	0.04	0.10	0.06	0.12
28	0.77	0.04	0.10	0.06	0.12
29	0.76	0.04	0.10	0.05	0.12
30	0.75	0.04	0.09	0.05	0.12

$$\text{Inclusive Limits} = \text{P.E. m} = \frac{\text{P.E. s}}{\sqrt{n}}$$

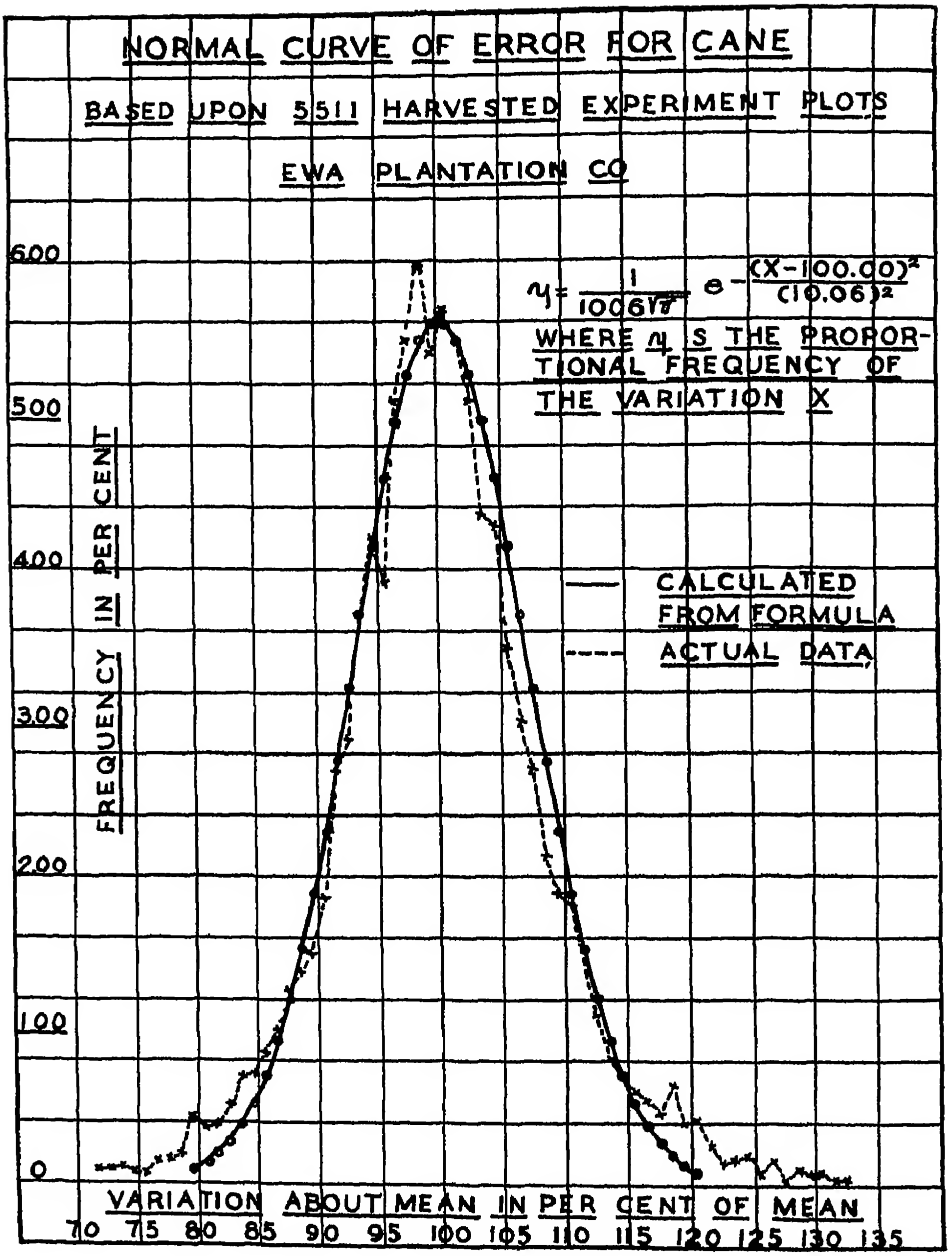

NORMAL CURVE OF ERROR FOR CANE
BASED UPON 5511 HARVESTED EXPERIMENT PLOTS
EWA PLANTATION CO
$y = \frac{1}{10.06\sqrt{\pi}} e^{-\frac{(X-100.00)^2}{(10.06)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
600
500
400
300
200
100
0
VARIATION ABOUT MEAN IN PER CENT OF MEAN
70 75 80 85 90 95 100 105 110 115 120 125 130 135

Fig 1

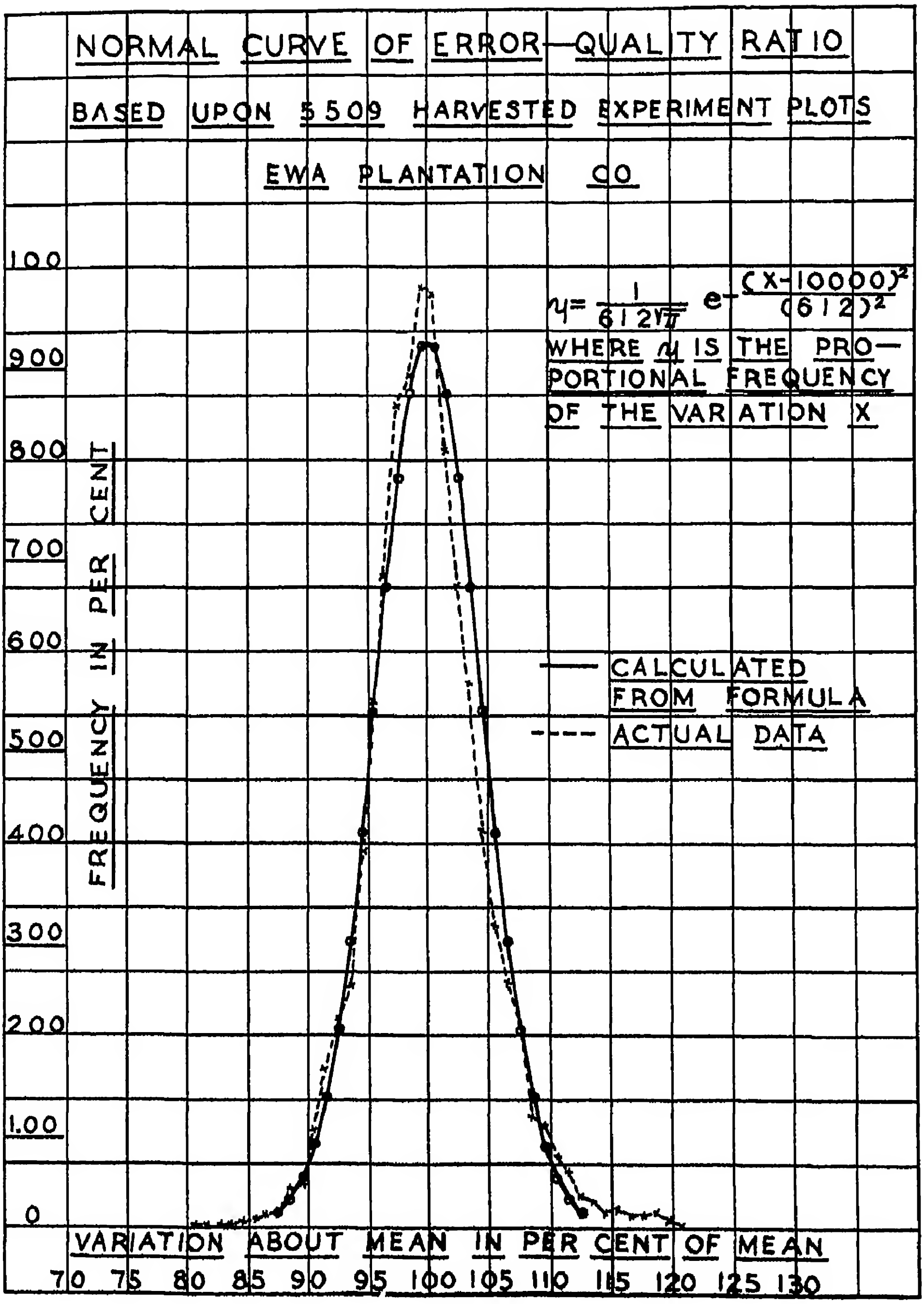

NORMAL CURVE OF ERROR—QUALITY RATIO
BASED UPON 5509 HARVESTED EXPERIMENT PLOTS
EWA PLANTATION CO
$y = \frac{1}{612\sqrt{\pi}} e^{-\frac{(x-10000)^2}{(612)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
100
900
800
700
600
500
400
300
200
1.00
0
VARIATION ABOUT MEAN IN PER CENT OF MEAN
70 75 80 85 90 95 100 105 110 115 120 125 130

Fig 2

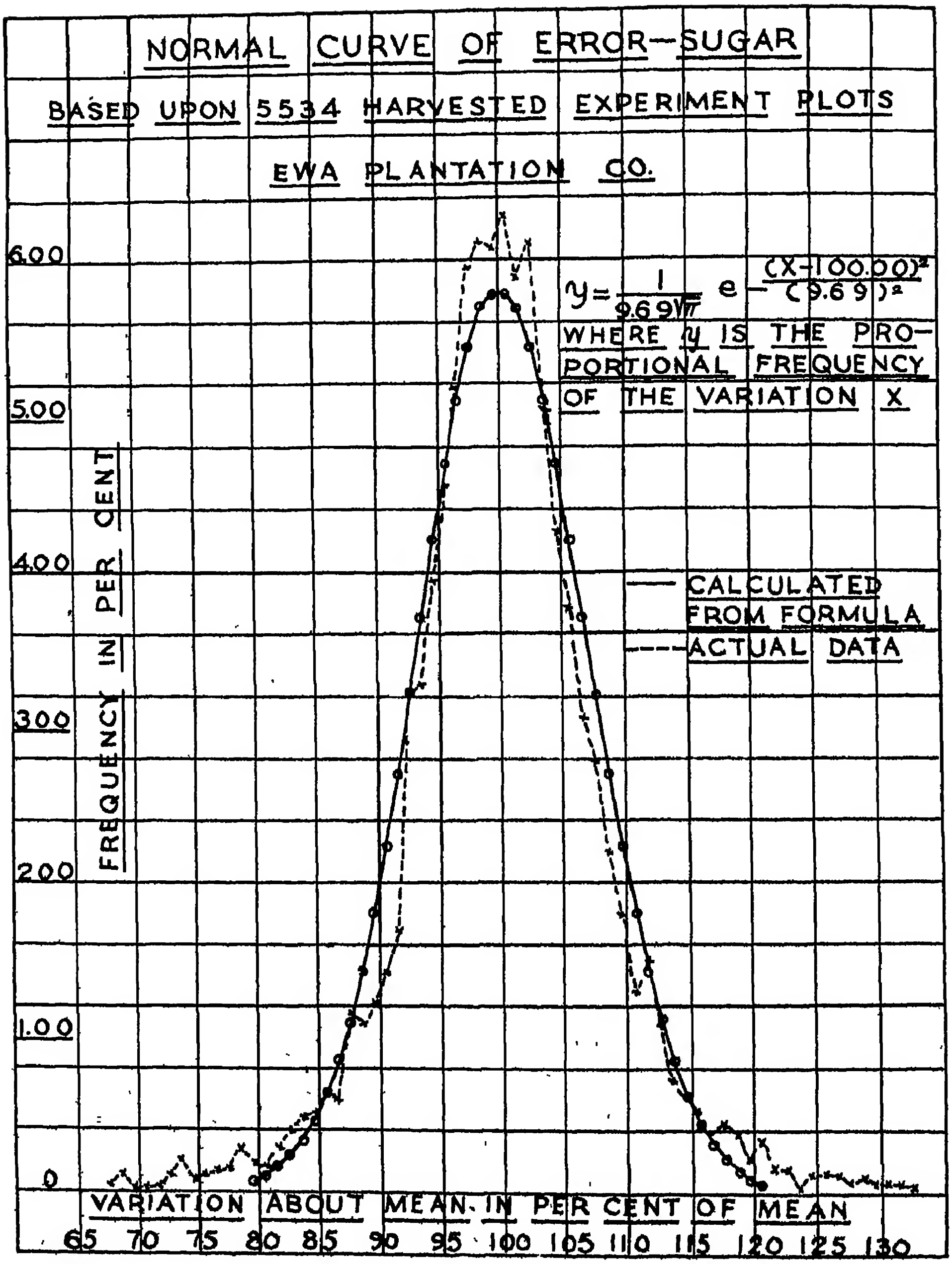

NORMAL CURVE OF ERROR—SUGAR
BASED UPON 5534 HARVESTED EXPERIMENT PLOTS
EWA PLANTATION CO.
$y = \frac{1}{9.69\sqrt{\pi}} e^{-\frac{(X-100.00)^2}{(9.69)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
6.00
5.00
4.00
3.00
2.00
1.00
0
VARIATION ABOUT MEAN IN PER CENT OF MEAN
65 70 75 80 85 90 95 100 105 110 115 120 125 130

Fig. 3

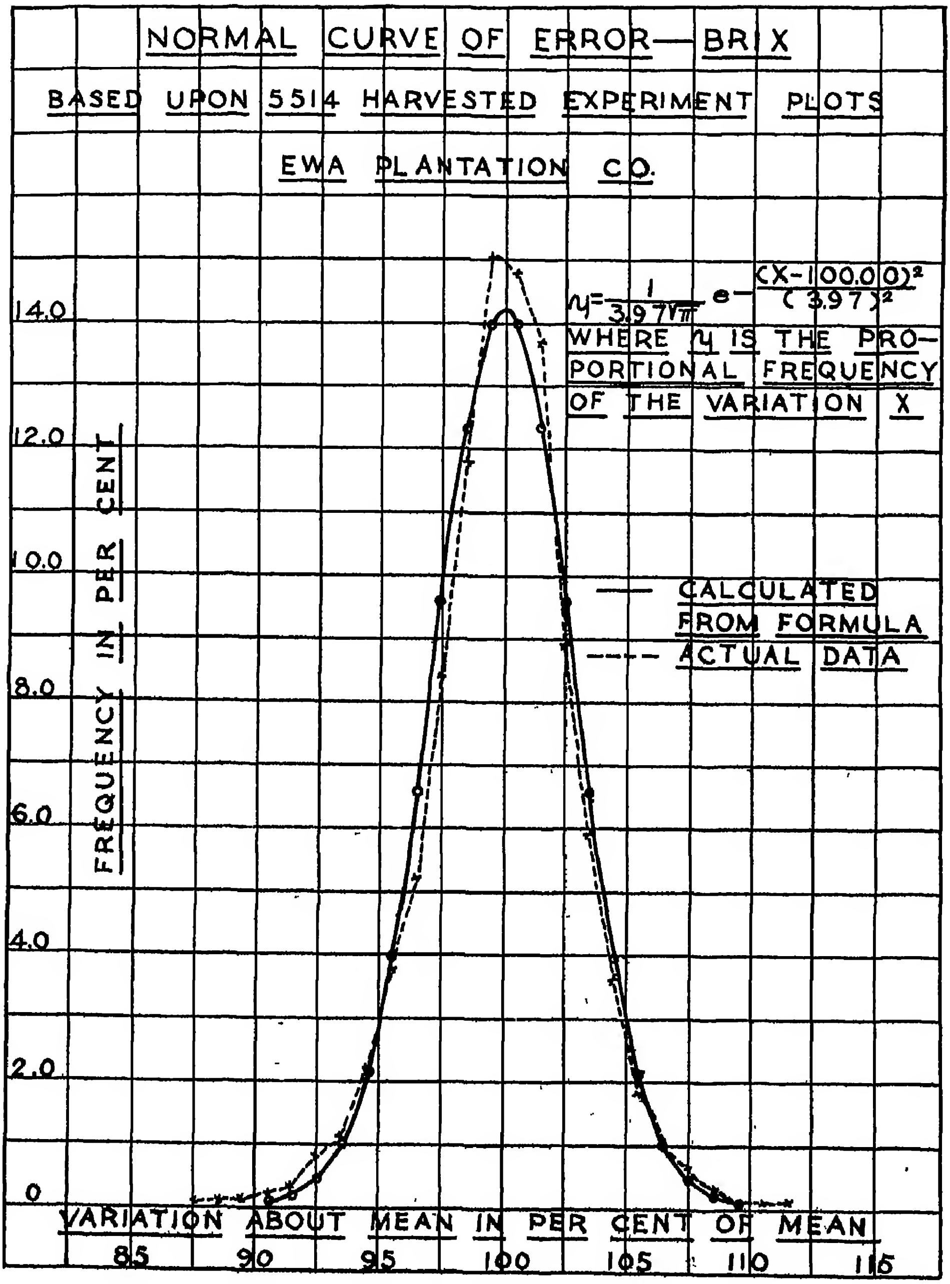

NORMAL CURVE OF ERROR—BRIX
BASED UPON 5514 HARVESTED EXPERIMENT PLOTS
EWA PLANTATION CO.
$y = \frac{1}{3.97\sqrt{\pi}} e^{-\frac{(X-100.000)^2}{(3.97)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
VARIATION ABOUT MEAN IN PER CENT OF MEAN
85
90
95
100
105
110
115

Fig. 4

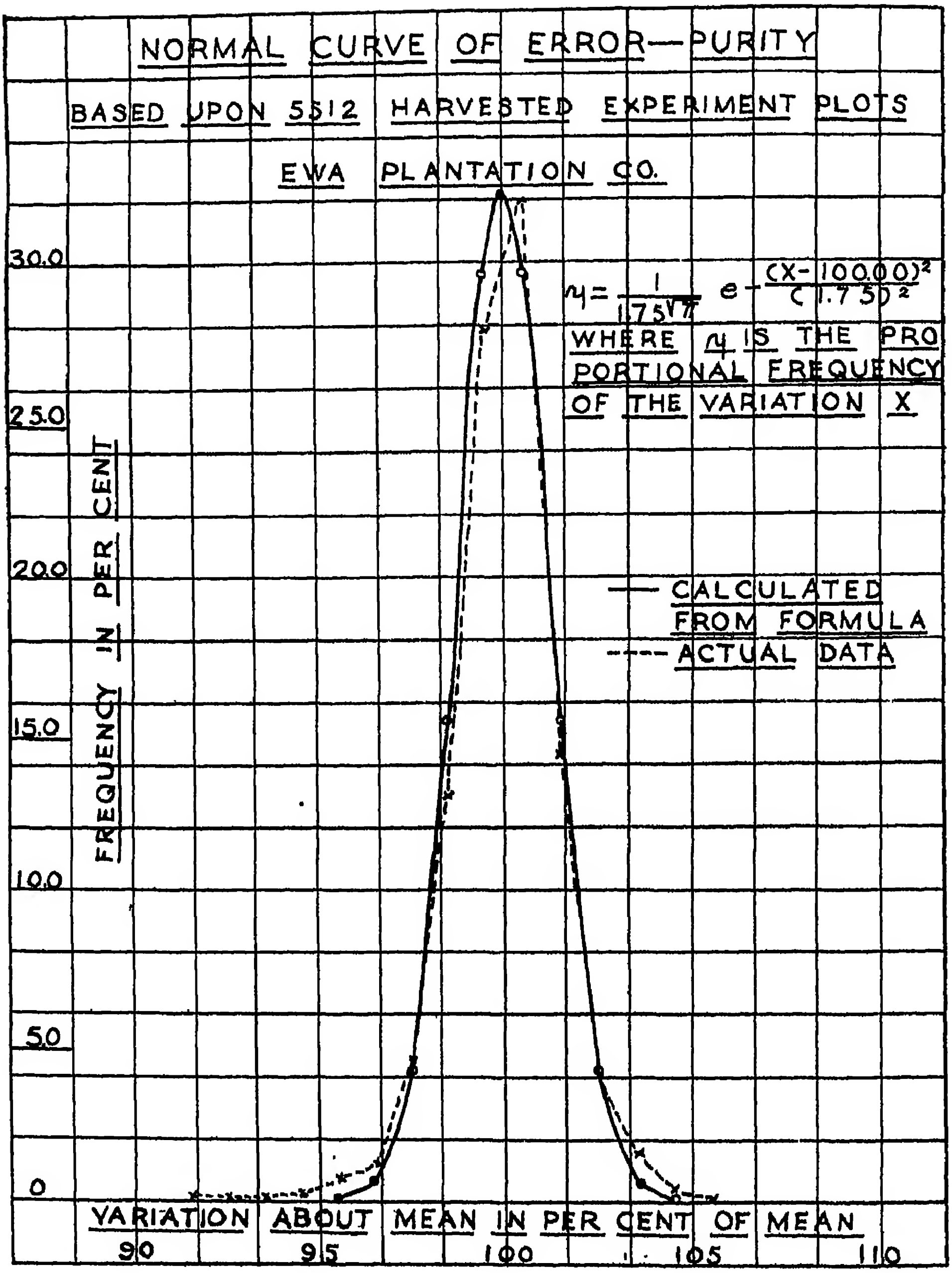

NORMAL CURVE OF ERROR—PURITY
BASED UPON 5512 HARVESTED EXPERIMENT PLOTS
EWA PLANTATION CO.
30.0
25.0
20.0
15.0
10.0
5.0
0
FREQUENCY IN PER CENT
$y = \frac{1}{1.75\sqrt{\pi}} e^{-\frac{(X-100.00)^2}{(1.75)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
VARIATION ABOUT MEAN IN PER CENT OF MEAN
90
95
100
105
110

Fig. 5

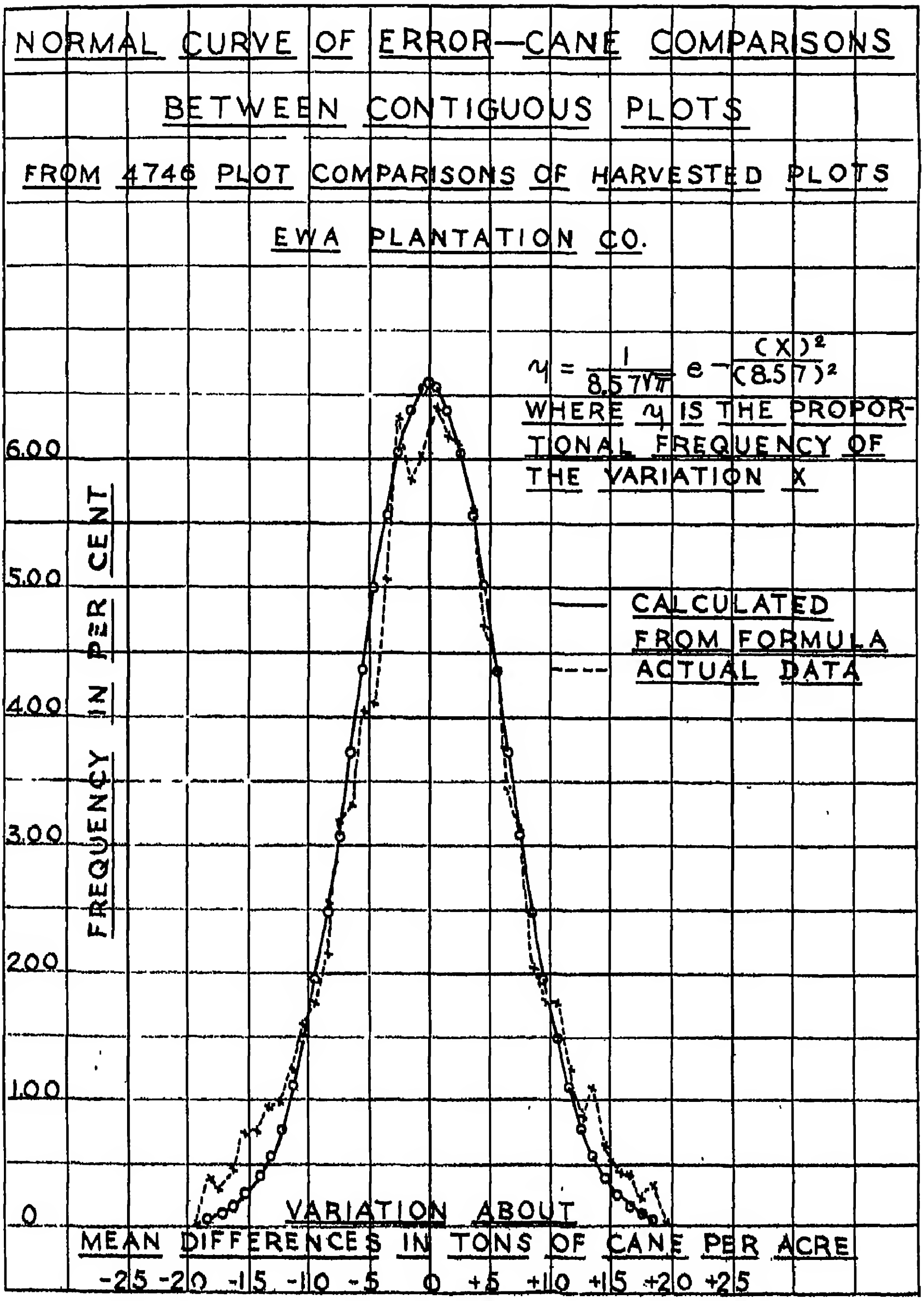

NORMAL CURVE OF ERROR—CANE COMPARISONS
BETWEEN CONTIGUOUS PLOTS
FROM 4746 PLOT COMPARISONS OF HARVESTED PLOTS
EWA PLANTATION CO.
$y = \frac{1}{8.57\sqrt{\pi}} e^{-\frac{(X)^2}{(8.57)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
6.00
5.00
4.00
3.00
2.00
1.00
0
VARIATION ABOUT MEAN DIFFERENCES IN TONS OF CANE PER ACRE
-25 -20 -15 -10 -5 0 +5 +10 +15 +20 +25

Fig. 6

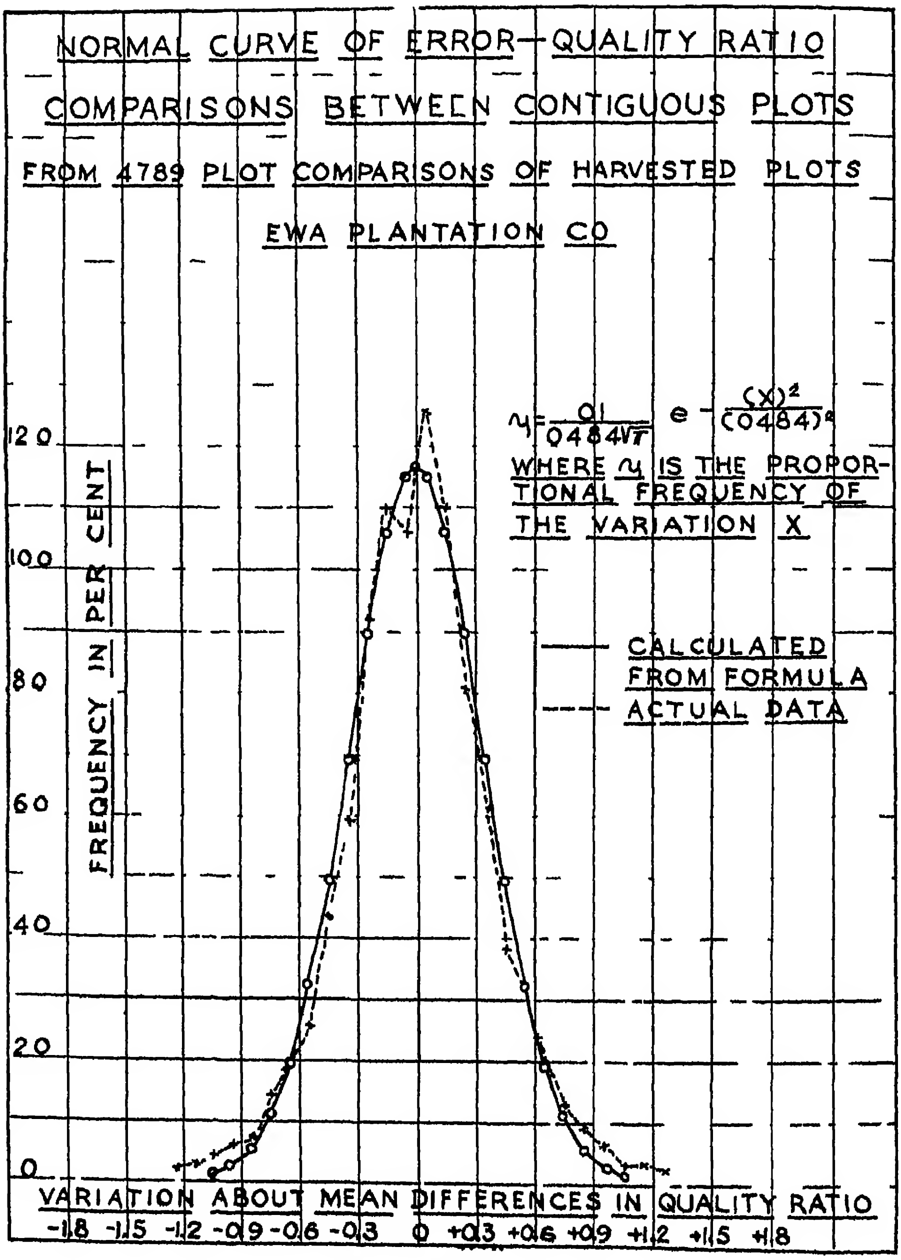

NORMAL CURVE OF ERROR—QUALITY RATIO
COMPARISONS BETWEEN CONTIGUOUS PLOTS
FROM 4789 PLOT COMPARISONS OF HARVESTED PLOTS
EWA PLANTATION CO
$y = \frac{0.1}{0.484\sqrt{\pi}} e^{-\frac{(x)^2}{(0.484)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
FREQUENCY IN PER CENT
120
100
80
60
40
20
0
VARIATION ABOUT MEAN DIFFERENCES IN QUALITY RATIO
-1.8 -1.5 -1.2 -0.9 -0.6 -0.3 0 +0.3 +0.6 +0.9 +1.2 +1.5 +1.8

Fig 7

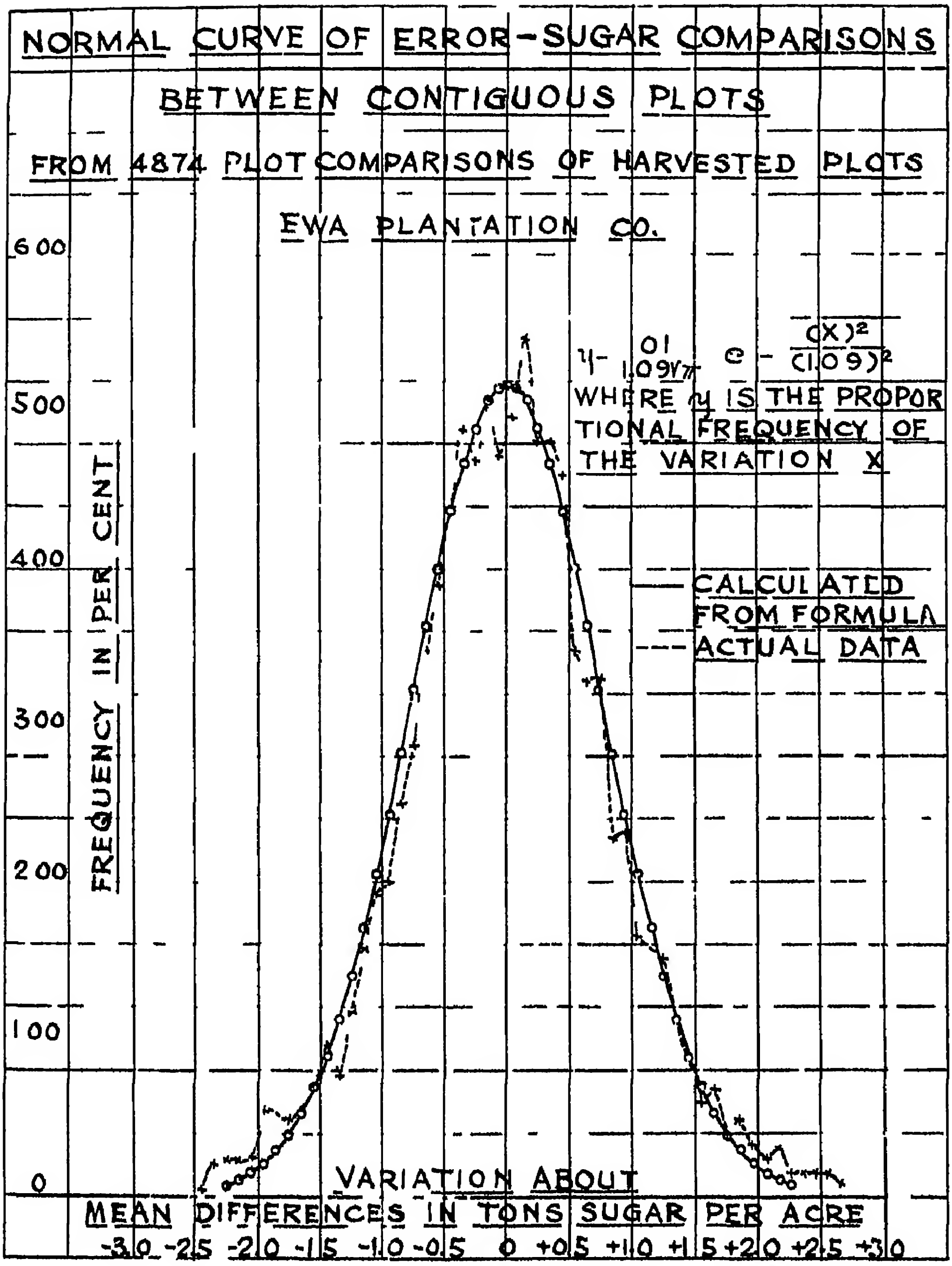

NORMAL CURVE OF ERROR—SUGAR COMPARISONS
BETWEEN CONTIGUOUS PLOTS
FROM 4874 PLOT COMPARISONS OF HARVESTED PLOTS
EWA PLANTATION CO.
600
500
400
300
200
100
0
FREQUENCY IN PER CENT
$y = \frac{0.1}{1.09\sqrt{\pi}} e^{-\frac{(x)^2}{(1.09)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION x
CALCULATED FROM FORMULA
ACTUAL DATA
VARIATION ABOUT
MEAN DIFFERENCES IN TONS SUGAR PER ACRE
-3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0 +0.5 +1.0 +1.5 +2.0 +2.5 +3.0

Fig 8

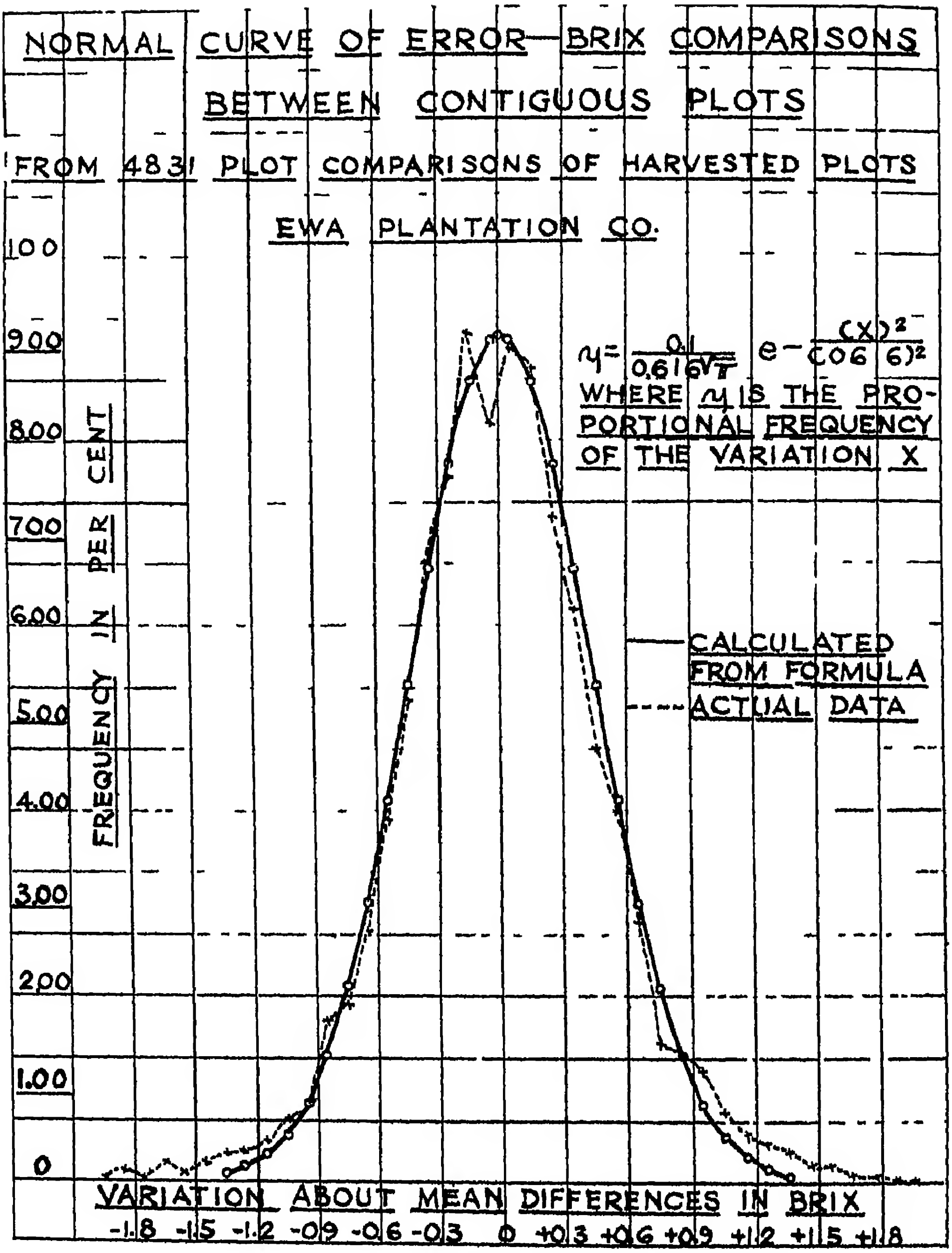

NORMAL CURVE OF ERROR—BRIX COMPARISONS BETWEEN CONTIGUOUS PLOTS
FROM 4831 PLOT COMPARISONS OF HARVESTED PLOTS
EWA PLANTATION CO.
100
900
8.00
700
6.00
5.00
4.00
3.00
200
1.00
0
FREQUENCY IN PER CENT
$y = \frac{0.1}{0.616\sqrt{\pi}} e^{-\frac{(x)^2}{(0.616)^2}}$
WHERE y IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
VARIATION ABOUT MEAN DIFFERENCES IN BRIX
-1.8 -1.5 -1.2 -0.9 -0.6 -0.3 0 +0.3 +0.6 +0.9 +1.2 +1.5 +1.8

Fig. 9

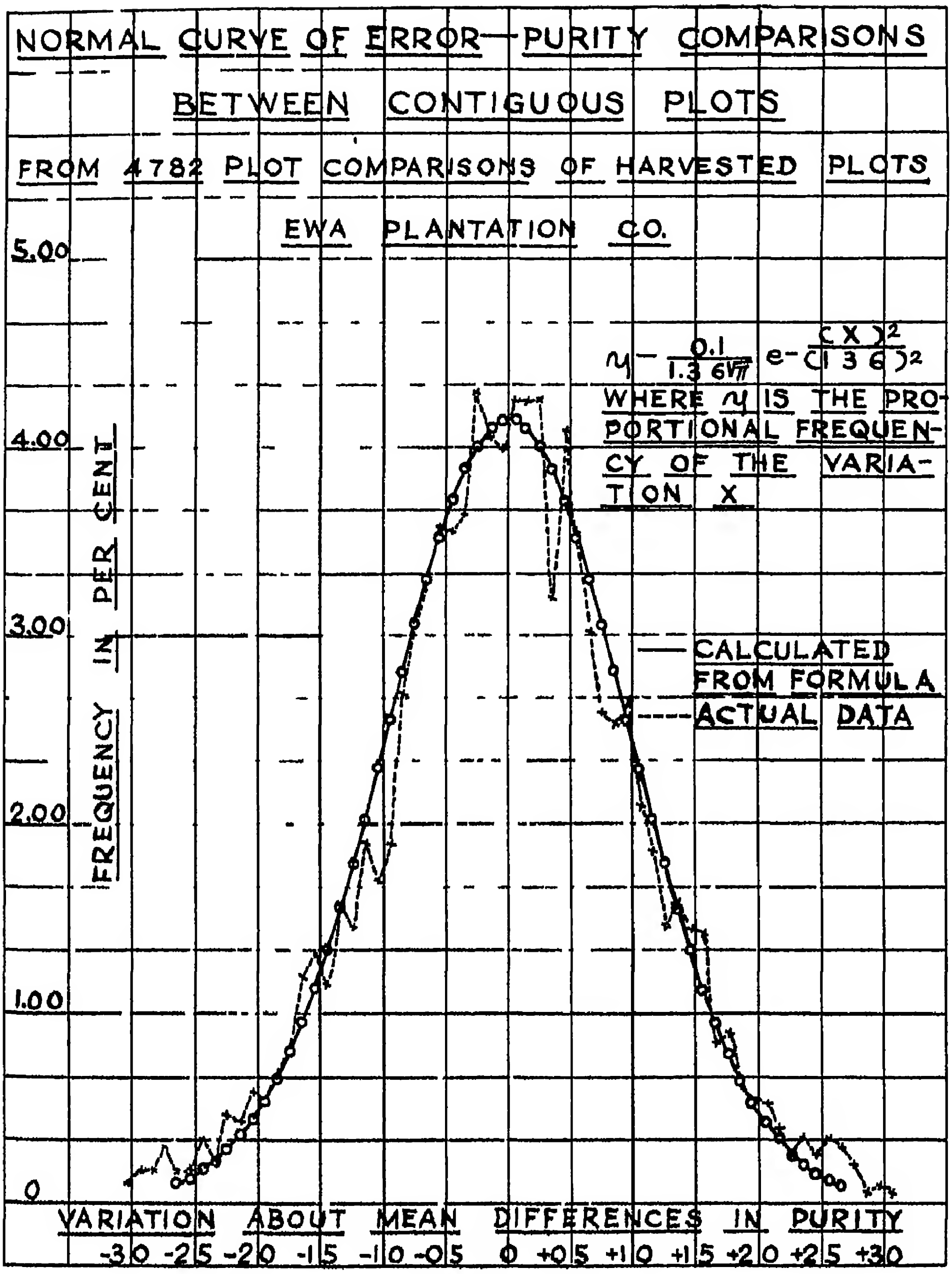

NORMAL CURVE OF ERROR—PURITY COMPARISONS
BETWEEN CONTIGUOUS PLOTS
FROM 4782 PLOT COMPARISONS OF HARVESTED PLOTS
EWA PLANTATION CO.
5.00
4.00
3.00
2.00
1.00
0
FREQUENCY IN PER CENT
WHERE η IS THE PROPORTIONAL FREQUENCY OF THE VARIATION X
CALCULATED FROM FORMULA
ACTUAL DATA
VARIATION ABOUT MEAN DIFFERENCES IN PURITY
-3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0 +0.5 +1.0 +1.5 +2.0 +2.5 +3.0

Fig. 10

Sugar Prices

96° Centrifugals for the Period June 16 to Sept. 15, 1930

Date		Per Pound	Per Ton	Remarks
June	16, 1930	3.335¢	$66.70	Cubas, 3.33, 3.34; Philippines, 3.33.
"	17	3.285	65.70	Cubas, 3.27; Porto Ricos, 3.30.
"	18	3.2533	65.07	Cubas, 3.24; Philippines, 3.25, 3.27; Porto Ricos, 3.27.
"	20	3.24	64.80	Cubas.
"	24	3.255	65.10	Philippines, 3.24; Porto Ricos, 3.27.
"	25	3.285	65.70	Cubas, 3.27, 3.30.
"	26	3.30	66.00	Cubas; Porto Ricos; Philippines.
"	27	3.38	67.60	Cubas, 3.35, 3.41; Philippines, 3.35, 3.38.
"	30	3.355	67.10	Cubas, 3.38; Porto Ricos, 3.33.
July	2	3.31	66.20	Cubas, 3.32; Philippines, 3.30.
"	7	3.30	66.00	Porto Ricos.
"	8	3.2833	65.67	Cubas, 3.27, 3.28; Philippines, 3.28, 3.30.
"	10	3.3167	66.33	Cubas, 3.32, 3.33; Philippines, 3.30; Porto Ricos, 3.30, 3.32.
"	11	3.3075	66.15	Cubas, 3.28, 3.32, 3.33; Porto Ricos, 3.30.
"	14	3.275	65.50	Cubas, 3.27, 3.28; Philippines, 3.28.
"	15	3.26	65.20	Cubas.
"	16	3.25	65.00	Cubas, 3.25, 3.26; Philippines, 3.24.
"	18	3.26	65.20	Cubas.
"	22	3.28	65.60	Cubas; Philippines.
"	24	3.255	65.10	Cubas; Porto Ricos.
"	25	3.25	65.00	Cubas.
"	28	3.22	64.40	Philippines.
"	29	3.195	63.90	Cubas, 3.20; Philippines, 3.19.
"	30	3.18	63.60	Cubas.
"	31	3.20	64.00	Cubas; St. Croix.
Aug.	5	3.205	64.10	Porto Ricos, 3.21; Philippines, 3.20.
"	7	3.2267	64.53	Cubas, 3.23, 3.25; Philippines, 3.20.
"	8	3.20	64.00	Cubas.
"	11	3.18	63.60	Cubas.
"	12	3.16	63.20	Philippines.
"	14	3.18	63.60	Porto Ricos; Philippines.
"	18	3.17	63.40	Cubas, 3.18; Philippines, 3.16.
"	19	3.16	63.20	Cubas; Philippines.
"	22	3.12	62.40	Philippines.
"	25	3.1233	62.47	Cubas, 3.12, 3.14; Philippines, 3.11, 3.12.
"	27	3.18	63.60	Cubas; Porto Ricos.
"	28	3.20	64.00	Cubas, 3.22; Philippines, 3.18; Porto Ricos, 3.18, 3.22.
Sept.	2	3.175	63.50	Philippines, 3.17, 3.18.
"	3	3.17	63.40	Porto Ricos, 3.16, 3.18.
"	4	3.15	63.00	Cubas.
"	5	3.155	63.10	Cubas, 3.15, 3.16.
"	8	3.15	63.00	Cubas.
"	9	3.135	62.70	Cubas, 3.14; Philippines, 3.13.
"	10	3.13	62.60	Cubas; Philippines.
"	11	3.14	62.80	Cubas.
"	12	3.15	63.00	Philippines.
"	15	3.14	62.80	Cubas; Porto Ricos, 3.15; Philippines, 3.13.